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# RESEARCH IN THE BUREAU OF PLANT INDUSTRY

By Dr. WM. A. TAYLOR
CHIEF OF THE BUREAU

SEVERAL times during the last few years the question has been asked, "Why not discontinue work upon the control of plant diseases and allow the ravages of these diseases to at least partially solve the problem of overproduction?"

The losses from plant diseases unfortunately fall unequally upon the producing public. An epidemic will affect only certain irregular areas, causing heavy damage to individuals farming there, the curtailment in production perhaps temporarily benefitting other regions. From the standpoint of the nation such irregularity of production is objectionable, because it not only injures or bankrupts certain groups of people but it increases the average cost of production for the entire country; it is not a cure for overproduction. Plant disease epidemics at best can give only temporary benefit in reducing the total crop and generally result in national injury due to lowered efficiency of production, lowered quality of product, and eventual increased acreage of crops affected. For with abandonment of disease control activities overproduction may occur and, unfortunately, may become more unpredictable than at present. Better adjustment of production to demand obviously must rest upon a steady basis of production, but it is in problems of quality rather than in more general problems of total yield that the importance of stabilized production from year to year is realized as a fundamental economic advantage for both the producer and the consumer. The importance of the utilization of better varieties of crop plants is one of the factors in reducing the costs of crop production and at the same time gaining in quality of the crop produced. Obviously the most dependable and therefore the most predictable results in both yield and quality can be secured by the simultaneous application of improved cultural and disease control practises and the utilization of improved crop varieties.

Investigations in plant physiology, genetics and plant pathology provide the necessary groundwork for the breeding of crops immune or highly resistant to formerly destructive plant diseases and for the development of cultural practises, spraying materials, and other practical methods for controlling losses from disease. The control of plant diseases through the breeding of resistant varieties is less spectacular than some other agricultural achievements, but the results of recent years establish this as the most economical and most effective

method of avoiding increasing losses in regions where climatic and other factors require large acreages of the same crops year after year. Agricultural research has not eliminated disease epidemics in crop production but it has reduced their severity.

From the outset the Bureau of Plant Industry has devoted a large part of its activities to the identification and study of destructive plant diseases and, although there is clearly great improvement in the production of many crops resulting from methods of disease control established by the Bureau and cooperating state agencies, in most cases it is difficult to estimate this benefit in financial terms. A few items which can be approximated with a reasonable degree of accuracy are:

### Savings from Disease Control

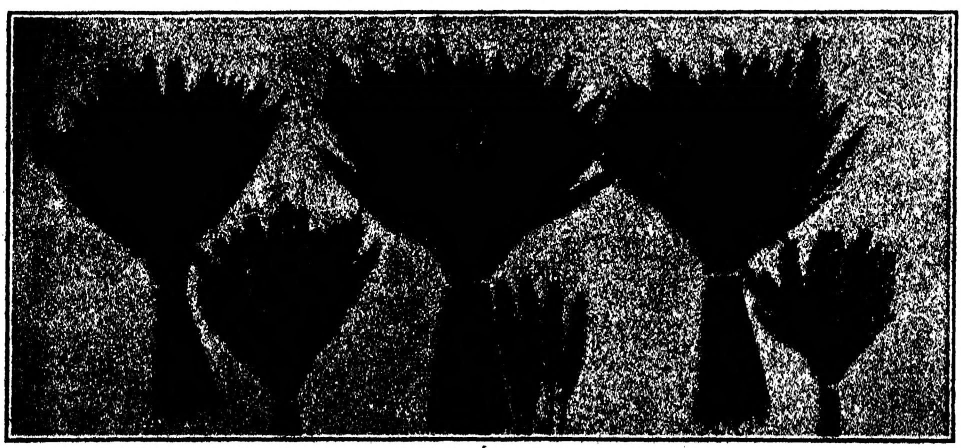
For the prevention of bunt disease of wheat, the copper-carbonate treatment applied to seed wheat has been extensively adopted in Minnesota, Montana, and on a small scale in the Dakotas, as well as in certain other areas. On the basis of reduced bunt infection, through improvement in seed disinfection methods ordinarily used, the net gain amounts to more than 5,000,000 bushels annually.

The discovery that heat canker of flax can be largely controlled by earlier seeding has resulted in a much wider application of this practise. On the average, better yields are obtained from early seeding, so the value resulting from this discovery is much greater than the direct one resulting from the control of the canker itself. It is conservative to estimate a gain of 500,000 bushels annually from earlier seeding.

In the prevention of peach-leaf curl and California peach blight through methods of spraying discovered by the Bureau an annual saving of about 2,000,000 bushels of peaches has been accomplished.

The development of self-boiled lime-sulphur spray gave growers a practicable control of brown rot and scab of peaches, and to growers of stone fruits this has saved 12,000,000 bushels annually.

The development of successful spraying and sanitation for apple bitter rot,



WHEAT SEED TREATMENT FOR SMUT CONTROL

From left to right: 50% healthy; 50% smutted (untreated seed); 96% healthy; 4% smutted (seed treated with copper carbonate); 72% healthy; 28% smutted (seed treated with formaldehyde).

blotch, scab and scald, and the development of the oiled wraps for apples have approximated annual gains or savings of 20,000,000 bushels of merchantable fruit.

### Improved Handling Methods

Previous to the 1909 orange crop the losses sustained by the California orange growers from the rotting of oranges in transit ranged from 8 to 20 per cent. of the total shipment, averaging around 12 per cent., and these losses seemed to be steadily increasing. Our specialists after laboratory and field investigations showed that by careful handling it was feasible to reduce the losses from rot in transit to less than 2 per cent. In addition to the actual increase in quantity of sound oranges delivered in the markets, the eating quality and therefore unit value of the crop has been enormously increased by the improved methods of handling and more efficient refrigeration practise and equipment, yet costs have been reduced. During the past year we concluded a series of demonstrations showing that oranges may be shipped from California to eastern markets by pre-cooling the fruit and loading in pre-iced cars which may be again refilled with ice by the shipper before moving, after which only one re-icing in transit is needed instead of ten to twelve as provided under the standard refrigeration previously employed. This one improvement alone will save upward of $30.00 a car, or will save orange growers a half million dollars or more a year.

### Eradication Campaigns

Sometimes the attack upon a plant disease appears to be more practicable through a campaign of eradication directed toward either the disease itself or some plant capable of transmitting or accentuating its ravages, rather than through spraying or similar control practises. Four extensive direct service campaigns in cooperation with the states concerned are under way for controlling the citrus canker disease in the Southeast, the white pine blister rust in both the eastern and western white pine areas, the barberry eradication campaign for control of black-stem rust of wheat in the spring wheat states, and the phony peach disease of the southern peach-growing states.

*Citrus canker.* The campaign for the eradication of citrus canker, a bacterial disease of citrus fruits and trees, was undertaken in 1915, in cooperation with the Gulf States, namely, Florida, Alabama, Louisiana, Mississippi and Texas. The disease has now been practically eliminated from the greater portion of the commercial citrus-growing region, and, with the exception of scattering infections in Louisiana and Texas, the disease appears to have been eradicated. There is no question but that the important citrus industry of the Gulf States has been saved by this intensive campaign.

*White-pine blister rust.* Only a few years ago it was doubtful whether the continued growing of the white pines in the Northeastern states was economically possible because of the destructiveness of the white-pine blister rust, a disease that was introduced from Europe on nursery stock. It spreads to the pines only after an intermediate development on Ribes (currant and gooseberry plants). Repeated experiments over a wide range of forest conditions in this country showed conclusively that these bushes could be successfully suppressed and the pines thereby protected on any area where the pine values justified the cost. White-pine areas aggregating more than 8,000,000 acres have been effectively protected from blister rust in New England and New York at an average cost of 21 cents an acre. These areas should be reworked system-

atically at about 5-year intervals, but the cost for these follow-up operations will be less than that of the initial work. The labor has been furnished by pine owners and local agencies, and supervision and direction have been supplied jointly by the Bureau and the affected states. These results, accomplished by systematic work throughout the region, assure the growing of a revenue-producing crop of white pine on millions of acres of nonagricultural land that would otherwise be a liability.

Climatic conditions in 1931 promoted the extensive spread of the white-pine

INFECTED BY BLISTER RUST

GROUP OF LARGE WHITE PINES. SINGLE BAND: TREES WITH TRUNK CANKERS. DOUBLE BAND: TREES KILLED. CROSS: TREES WITH BRANCH CANKERS ONLY.

blister rust in the eastern part of the United States. From the generally infested northeastern region the disease spread into the bordering states of Maryland, Virginia, West Virginia and Ohio. In the Lake States region it was found in several new places, including one in Iowa. In the commercial areas of western white pine in northern Idaho, 45 additional centers of pine infection were found, showing the rust to be firmly established in that region. The disease was again found on Ribes in southwestern Oregon within 40 miles of the California line and within the range of valuable forests of sugar pine which are known to be susceptible. It now appears certain that the rust will reach the main sugar-pine belt of California.

The problem of controlling the rust in the western part of the United States is comparatively new because of the more recent discovery and spread of the disease in that part of the country. Forest conditions differ entirely from those in the East, where the large-scale application of effective control measures is under way, and require new methods for destroying Ribes. Good progress has been made in developing and applying these methods in cooperation with the affected states and local agencies.

*Barberry eradication.* The campaign to eradicate the common barberry, for the purpose of reducing stem-rust losses of small grains, was undertaken in 1917 with Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and Wyoming. It is evident that barberry eradication is a material aid in the solution of the stem-rust problem. A single infected barberry bush has been known to cause a local loss to wheat growers, in one township in one year, of more than 10,000 bushels of grain. In the eastern winter-wheat producing states of the eradication area stem rust of wheat is controlled as soon as the barberries are eradicated from a locality. Since 1918 more than 18,000,000 rust-spreading barberry bushes have been destroyed in the 13 more important small grain-growing states. Of these 18,000,000 bushes some were planted for orna-

mental and hedge purposes but a larger percentage grew from seed scattered by birds. With the eradication of these bushes there has been a steady reduction in the number and severity of stem rust epidemics. The following table shows that losses from stem-rust decrease as progress is made in barberry eradication:

LOSSES FROM STEM RUST DECREASE AS PROGRESS IS MADE IN BARBERRY ERADICATION

| Wheat losses resulting from black stem rust in 13 northern states by 5-year periods. | | |
|---|---|---|
| 1916–20 | 285,000,000 | bu. |
| Average annual loss | 57,000,000 | " |
| 1921–25 | 85,000,000 | " |
| Average annual loss | 17,000,000 | " |
| 1926–30 | 45,000,000 | " |
| Average annual loss | 9,000,000 | " |

| Rust-spreading barberry bushes destroyed since beginning of stem-rust control program. | | |
|---|---|---|
| 1916–20 | 4,000,000 | bu. |
| 1916–25 | 12,000,000 | " |
| 1916–30 | 18,000,000 | " |

Had there been no organized effort to free the northern small grain-producing states from barberry these bushes would have continued spreading at a steadily increasing rate resulting in more numerous and more destructive epidemics of the disease.

*Phony peach eradication.* In the cooperative campaign for the eradication of the phony peach disease 40,538,560 trees have been inspected from 1929 to 1932 inclusive and 449,754 infected trees were found, as follows:

| | | | |
|---|---|---|---|
| **Alabama** | **8,908** | **Missouri** | **17** |
| **Arkansas** | **568** | **North Carolina** | **50** |
| **Florida** | **323** | **Oklahoma** | **3** |
| **Georgia** | **437,038** | **South Carolina** | **196** |
| **Illinois** | **14** | **Tennessee** | **59** |
| **Louisiana** | **777** | **Texas** | **633** |
| **Mississippi** | **1,168** | | |

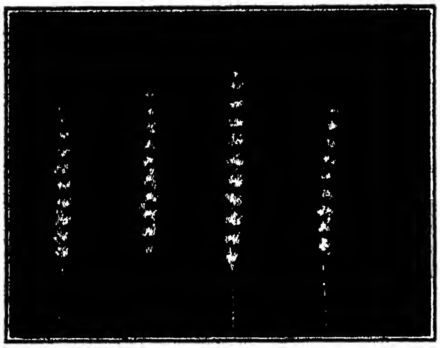
FIELD CREW

ERADICATING WILD CURRANTS TO PROTECT WHITE PINE FORESTS FROM BLISTER RUST DISEASE.

In the inspection carried on in 1930 and 1931 no diseased trees were found in Connecticut, Delaware, Indiana, Kansas, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia and West Virginia. At the present time, so far as is known, the disease does not occur north of North

WHITE PINE BLISTER RUST

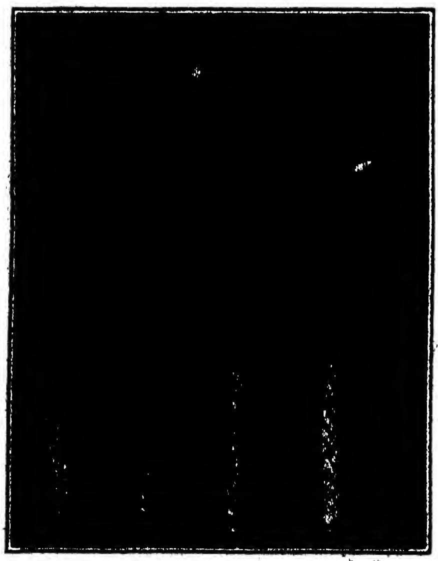
A DESTRUCTIVE DISEASE OF WHITE PINES. INSPECTOR HAS ONE HAND AT THE TOP AND ONE AT THE BOTTOM OF THE BADLY CANKERED AREA.



IMPORTANT VARIETIES OF COMMON WHEAT

FROM LEFT TO RIGHT: MARQUIS; POWER FIFE; HAYNES BLUESTEM; PRESTON. (ABOUT ONE EIGHTH NATURAL SIZE.)

Carolina and Tennessee, except as indicated. Most of the outlying infections, as in North Carolina, Tennessee, Illinois, Oklahoma and Missouri, are isolated ones, indicating that the disease was introduced into these states through the movement of infected nursery stock.



SELECTIONS OF DURUM WHEAT HEADS

FROM LEFT TO RIGHT: KUBANKA; ARNAUTKA; D-5; PELISS. (ABOUT ONE SEVENTH NATURAL SIZE.)

In Georgia, where the disease is most serious and where the most active work has been carried on, as a result of the eradication campaign the number of infections has been materially reduced. In the heavily infested territory in Georgia, where whole orchards of from 25,000 to 50,000 trees were removed because of the phony disease, the growers are watching the campaign very closely, basing their future actions on the results achieved in eradication or at least controlling the disease.

### PLANT BREEDING TO SUBDUE DISEASE

The potato is the leading vegetable of the United States. More than a decade ago the so-called "running out" of good varieties due to the potato diseases now referred to as mosaic, leafroll, spindle tuber and streak had become the greatest handicap to potato growing and to crop improvement for producers throughout the country. These virus diseases, carried from year to year in the tubers of the diseased plants and more widely spread in the field by aphids or plant lice, had led to the belief that potato varieties were all subject to weakening or "running out" after a few years' growth in a region and there was therefore a constant search for new varieties of potatoes and simultaneous discarding of some of the most important productive varieties. Our researches not only showed that the "running out" was due to an obscure group of infectious diseases but also established the practicability of commercial elimination of these virus diseases from potato seed stocks and demonstrated the value to the grower of market potatoes of insisting upon seed potatoes known to be free of these diseases. From this work has come the modern supervision by state officers of potatoes grown for seed and the development of a wide-spread interest in the use of cer-

tified seed potatoes for market production. It is estimated that the potato growers of the country have been saved millions of dollars annually through the use of the almost completely disease-free certified seed potatoes. Disease control and crop improvement can go hand in hand for many reasons, and among them plant breeding deserves especial mention.

Another virus disease affecting sugar beets in the western areas of production known as the curly-top disease of sugar beets and disseminated by the beet leaf-hopper has resulted in very heavy losses both to beet growers and to sugar companies for many years. Researches relating to this problem are approaching a commercial success through the development of strains of sugar beets of satisfactory sugar yield and cultural qualities and with the added advantage of partial immunity or tolerance toward the curly-top disease. Beet strains recently developed in test experiments have produced satisfactory yields of beets or sugar per acre under conditions of beet leaf-hopper and curly-top infestation that were sufficiently severe to destroy crops of sugar-beet strains ordinarily used. At the present time increase in seed supplies is being arranged for and within a comparatively few years the losses to the western sugar industry from curly-top probably will be eliminated.

Occasionally by rare good fortune it occurs that the work of plant breeders in regions where research work on the crop has been longer under way is unexpectedly found to meet a critical need. Thus, when the mosaic disease of sugarcane threatened the very existence of the sugar industry of our Gulf States a few years ago, it was rather promptly found that certain cane varieties, bred in and for the tropical sugar industry of Java, were both fairly well suited to the conditions of our Louisiana sugar belt and satisfactorily resistant to the mosaic diseases. Their availability for the prompt replacement of the disease-susceptible canes made possible the prompt resuscitation of the industry. This is evidenced by the quadrupling of the actual production of sugar in Louisiana between 1926 and 1929. It is recognized, however, that the Javanese varieties of cane do not possess all the characteristics desirable for the perma-

CHINESE ELM, *ULMUS PUMILA*
INTRODUCED INTO THIS COUNTRY BY FRANK N. MEYER. PARTICULARLY ADAPTED TO THE GREAT PLAINS REGION, BOTH AS AN ORNAMENTAL AND A WINDBREAK.

nent maintenance of our cane-sugar industry upon a prosperous basis. Accordingly, an airplane expedition sent by the Department to New Guinea in 1928, with the active cooperation of the industry, has assembled and brought back to this country as breeding stock more than 100 primitive varieties and strains of cane from which it is hoped through combination with existing varie-

ties to produce better sorts for our exacting conditions.

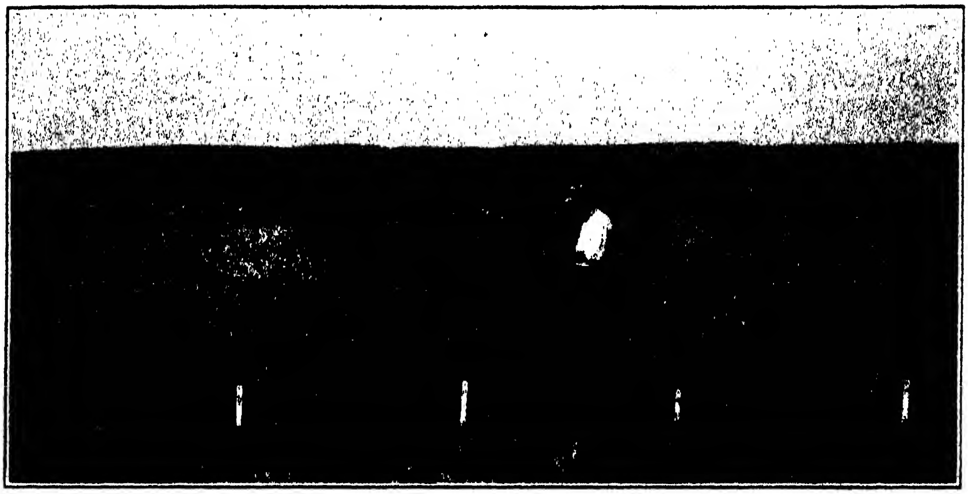
*Breeding and adaptation of varieties.* Experiments conducted in cooperation with Funk Bros. Seed Co. and the Illinois Agricultural Experiment Station, using a portable field refrigeration chamber in which temperatures can be automatically controlled, have shown that certain inbred strains of corn and their hybrids are highly sensitive to temperatures above the freezing-point as they approach maturity. Other strains and hybrids are uninjured by such temperatures. Some strains are able to resist temperatures even slightly below the freezing-point. These experiments explain field observations of the behavior of these varieties. It also has been found that corn tissues injured by frost are unusually susceptible to such fungi as *Diplodia zeae* and *Basisporium gallarum.* Seed matured on the corn plants high in cold resistance produced plants much more resistant to seedling blights, lodging, and stalk breaking and thus establish improvements in seed corn selection.

### Better Varieties

Extensive corn-breeding investigations at several cooperating experiment stations have given impressive evidence of the value of the new methods being used. Many strains developed in the various cooperative breeding programs yielded from 10 to 50 per cent. more than the best local varieties in experiments in Virginia, South Carolina, Kansas, Nebraska, Iowa and Ohio. Four strains, which were developed in the breeding program carried on cooperatively with the Iowa Agricultural Experiment Station and entered in the Iowa yield test, produced 10, 9.7 and 7.8 bushels per acre more than the best of the open-pollinated varieties in the northern, north-central, south-central and southern sections, respectively. In some cooperative experiments with the Ohio Agricultural Experiment Station marked differences were found in the

FIELD OF EGYPTIAN COTTON OF THE PIMA VARIETY

GROWING IN THE SALT RIVER VALLEY OF ARIZONA. THIS COTTON PRODUCES A STRONG FIBER $1\frac{1}{4}$ TO $1\frac{5}{8}$ INCHES LONG, USED IN THE MANUFACTURE OF FABRICS COMBINING FINE QUALITY AND GREAT STRENGTH.



STUDYING THE COMPARATIVE BEHAVIOR OF FOREIGN WHEAT VARIETIES IN NORTH DAKOTA.

ability of strains of corn to respond to fertilizer applications. Two crosses were grown both without fertilizer and with an application of 16 tons of manure and 800 pounds of commercial fertilizer per acre. The first yielded 36.3 bushels without and 49.6 bushels with fertilizer, a difference of only 13.3 bushels, whereas the second yielded 43.9 bushels without and 70.7 bushels with fertilizer, a difference of 26.8 bushels, or twice the increase of the first.

Newturk is an awnless, hard, red winter wheat developed in the Bureau's breeding program. It has been widely tested for adaptation in the western United States. In cooperation tests in Montana it has been found equal to Kharkof and Karmont, standard hard red winter varieties, in yield, winter hardiness, and quality. There is a continuing demand for an awnless winter wheat in the western area. This variety meets that need and has been distributed for commercial growing in Montana.

In 1930 the varieties Tenmarq, bred in cooperative experiment at the Kansas station, Oro, selected in cooperative experiments at the Moro, Ore., branch station, and a selection from Crimean Cheyenne (Nebraska No. 50), from the Nebraska station, proved to be the most promising new varieties in the southern and central United States.

In the north-central hard red spring wheat area, the breeding program is largely centered around hybrids between the Hope variety and the best commercial varieties, Ceres, Marquis and Reliance. Hope, in addition to its high resistance to stem rust, is also highly resistant to stinking smut. Certain selections from these crosses have been entirely free from rust under all conditions where tested, and in addition are resistant to stinking smut. The best of these strains also are high yielding and from such information as is available would seem to be of satisfactory commercial quality.

### Regional Adaptability

The demand for information regarding the adaptability of alfalfa seed from various sources has been greater than ever before and has necessitated increased attention to this phase of alfalfa investigations. New tests were therefore started in cooperation with agricultural experiment stations in the East

and in the Corn Belt, and the work was enlarged at stations where work was already under way. The results of the past year's work bear out the previous tests in showing that none of the imported alfalfas are superior to some of our domestic strains for any part of the United States with the possible exception of those districts where bacterial wilt is prevalent. Most of the seed from foreign sources, however, is fairly satisfactory when sown in those limited areas to which the seed is adapted. Argentine alfalfa has given good results in the South, though seldom equaling the best domestic strains in yield. The use of seed from that source in the North ordinarily results in serious losses through winter killing. Recently considerable interest has developed in Turkestan alfalfa in the Middle West, because of the apparent resistance of certain strains from that source to the bacterial wilt. This statement, however, must be accepted with some reserve for the present, for the evidence is by no means complete. The importance of the wilt problem and the observational evidence from old fields warrant a continuance of this line of work, and further studies are under way to determine definitely the resistance of this strain to bacterial wilt.

Since the passage of the seed-staining amendment to the Federal Seed Act, samples representing most of the lots of red clover imported have been subjected to field tests. The records show that the red-clover seed imported into this country during recent years gives results far below those obtained from the use of domestic seed. It is evident that a larger production of domestic seed is necessary. With a view toward encouraging production in favorable parts of the intermountain states, a survey was

DATE PRODUCTION IN SOUTHERN CALIFORNIA

A NEW INDUSTRY FOR THE UNITED STATES. THE BUNCHES OF DATES ARE PROTECTED FROM SHOWERS AND FROM DUST UNTIL PICKING TIME.

made and arrangements completed for trials by 36 selected farmers in 22 counties of 5 states. While favorable conditions of climate and soil were naturally taken into account, the economic factors were also studied and an effort was made to establish trials in sections so far from the railway that the hauling of hay or grain had proved unprofitable. Clover seed having a high unit value can be hauled longer distances. The establishment of a clover-seed growing industry should, therefore, be of benefit to the residents of these intermountain states as well as to the eastern consumer of red-clover seed.

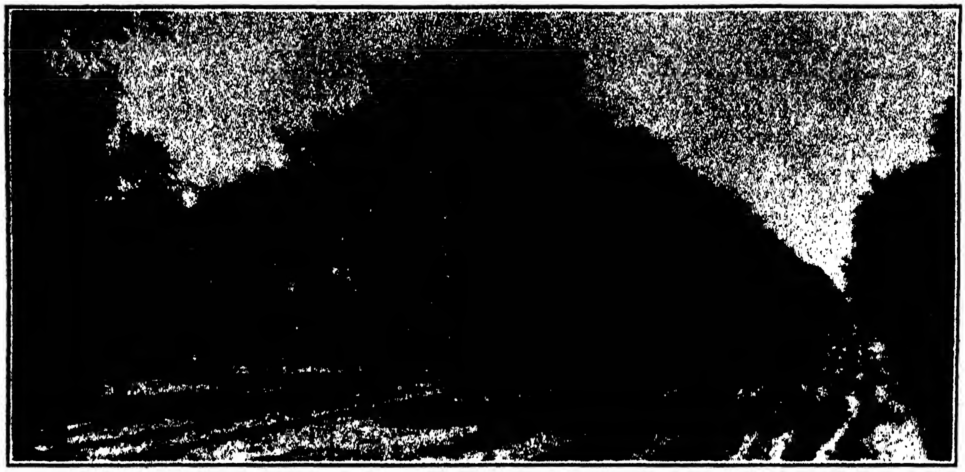
### Single-Variety Cotton Communities

As a result of intensive studies of cotton-production problems in the United States by specialists of the Bureau of Plant Industry, superior varieties of cotton have been bred, while others have been discovered and introduced from abroad and developed in this country, including such varieties as Acala, Lone Star, Columbia, Trice, Foster, Express, Durango, Meade and Pima. The Acala cotton, a superior upland variety producing a premium staple, was discovered in 1906 in a remote region of southern Mexico by an expedition sent out by this department. It was introduced, selected and established in cultivation in the United States. It is estimated that the 1925 cotton crop of California and the Mexican Imperial Valley (practically all of the Acala variety) had a value of $27,200,000. For the 7-year period from 1919 to 1925, inclusive, the cotton crop of California, including the Imperial Valley district in Lower California, had a total value of $126,543,000, which was largely the result of planting superior varieties of cotton introduced and developed by the specialists of this bureau. With the exception of a small acreage of the Pima Egyptian cotton in the Salt River Valley of Arizona, practically the entire irrigated cotton area of western Texas, New Mexico, Arizona and California is now producing Acala cotton. The Acala cotton is also being grown on hundreds of thousands of acres in the natural rainfall regions of Texas, Oklahoma and Arkansas.

Continued encouragement has been given by the Bureau to community cooperation in the growing of a single superior variety of cotton as a means of improving quality and establishing uniformity of product and thereby obtaining better prices. The present crisis resulting from overproduction of cotton of inferior quality emphasizes the importance and need of such a plan.

Statistics of recent years from manufacturing countries in Europe show a notably increasing use of cottons from other producing countries and a relative decline in the use of American cotton. The loss of our export market is threatened unless the tendencies to deterioration can be checked. American manufacturers are handicapped by the lack of enough good fiber, and much of the American export ~~product is of a grade~~ that comes into direct competition with the very short staples of India and China. The present production of millions of bales of inferior fiber in the United States is a vast and needless waste of farm labor and resources. With better varieties available, as early and as productive as the very short staples, no agricultural reason exists for planting varieties with less than 1-inch staple in any part of the United States.

A general effort is now being made to establish the production of better qualities of fiber in the United States. Fine fabrics are again in demand as the world recovers from the stress of the war period. Larger quantities of strong and uniform fiber are needed in the automobile industry, and new require-



A GROVE OF WASHINGTON NAVEL ORANGE TREES
A TREMENDOUS INDUSTRY BASED ON A FEW TREES INTRODUCED FROM BRAZIL THROUGH THE FEDERAL GOVERNMENT IN 1871.

ments are being recognized for fabrics of the greatest possible strength in airplanes, balloons, dirigibles and parachutes.

The first practical step for regional improvement in cotton is dependent upon the adequacy of supplies of select seed year after year, and this is feasible only in communities or districts where the farmers unite upon the production of a single variety.

### Citrus Improvement by Bud Selection

A striking illustration of benefit to the citrus industry as an outgrowth of research work is that resulting from the bud selection for nursery propagation, based upon tree-performance records. The per-acre production of oranges previous to the inauguration of the improvement of orchards by bud selection was so small that the annual output per acre averaged only about 1 box per tree, and at a tree price of less than $1 per box the income was hardly sufficient to maintain the groves even at the then low cost of labor. With the improvements resulting from bud selection and an equal number of acres in oranges, the per-acre production has very greatly increased, so that the industry during recent years has been fairly remunerative and in some particular groves highly remunerative. The elimination of the nonproductive and nonpaying trees through top-working them with productive strains, and the planting of new orchards the trees of which were propagated from highly productive parent trees, have resulted in a decided increase in total production with a relatively small increase in the total acreage devoted to the industry. It is very difficult to estimate the value which this activity has really contributed to the industry. Like compound interest, it accrues each year with the recurrence of the annual crop, and as the trees grow older and larger and produce more, the effects of the system become more and more apparent both in the harvest and in the total profit of the industry. It is safe to say that several millions of dollars have been contributed to the citrus industry of California as a result of the elimination of nonproductive trees through the principles of fruit improvement by bud selection.

The principles of bud selection, which were first discovered and clearly established in connection with the citrus industry, are found to apply in many lines of deciduous fruit production as well and are more or less applicable to all of the economic plants propagated by budding, grafting, or other vegetative methods. The far-reaching character of these principles will exert constantly increasing benefit on production as time and opportunity afford increasing application to commercial problems.

### Introducing Foreign Plant Varieties

Among the first of the major activities of the Bureau was the study of foreign cereals and the selection and introduction of certain important varieties for trial in the United States. The first introduction of a new grain upon a large scale was the establishment of the durum varieties of wheat introduced from Russia, which are adapted to certain severe climates of the United States where the varieties of wheat previously grown were unsuited. As a result durum wheats have added 50,000,000 bushels annually to the wheat crop of the country. Other outstanding examples include hairy Peruvian alfalfa, an important variety in California and Arizona with an annual value of about $5,000,000; the date palm in several varieties, well established in the Southwest; Sudan grass, with an annual crop worth $10,000,000; Barouni olive; the Meyer lemon; the avocado and mango in variety; the dasheen; the jujube; the Quetta nectarine; the Japanese flowering cherries; and a wide range of other field and vegetable crop varieties, fruits, and ornamental shrubs and trees. The soy-bean crop, with an estimated total annual value of nearly $100,000,000, consists of many varieties; the Department has introduced over 5,000 varieties, and selections from these form the basis of the present crop. The Chinese elm, rapidly becoming one of the most widely planted shade and

WAGON LOADS OF SEED COTTON WAITING TURN AT THE COTTON GIN

In a mixed variety community each wagon may represent a different variety. Mixing the seed at the gins is responsible for rapid mongrelizing of varieties, resulting in irregular inferior fiber.

COMBED FIBER ON THE COTTON SEED FROM SUCCESSIVE PLANTS GROWN FROM SELECTED SEED, COMPARED WITH COMBED FIBER FROM SUCCESSIVE PLANTS GROWN FROM MIXED, GIN-RUN SEED. NOTE THE UNIFORMITY OF FIBER IN THE SELECTED STOCK (FIRST AND THIRD ROWS) AND THE IRREGULARITY OF FIBER IN THE UNSELECTED STOCK (SECOND AND FOURTH ROWS). (ABOUT ONE EIGHTH NATURAL SIZE.)

shelter-belt trees of the Great Plains region, was first introduced from China by an agricultural explorer.

### Rubber

A rubber-producing plant, *Euphorbia intisy*, unusual in its special adaptation to desert conditions, was introduced from southern Madagascar in 1928, and is being propagated and its behavior is being tested at field stations in California and Florida. All of the principal types of tropical rubber trees, including American, African and Asiatic species, have produced vigorous individuals and most of the species have flowered and fruited in Florida. The Hevea or Para rubber tree of Brazil, the principal commercial species grown in the West Indies, flowered and fruited for the first time in Florida during the season of 1931 at the U. S. Plant Introduction Garden, a few miles south of Miami. While commercial production of rubber in the United States under existing conditions is not practicable, in view of the exceptionally wide use of rubber in the United States it is important to be prepared to undertake continental development if any urgent need should occur.

TAPPING A HEVEA RUBBER TREE IN HAITI, W. I., WHERE TAPPING EXPERIMENTS WERE CONDUCTED BY THE U. S. DEPARTMENT OF AGRICULTURE. YIELDS AND QUALITY OF RUBBER OBTAINED FROM THESE TREES, WHICH ARE GROWING HUNDREDS OF MILES BEYOND THE SUPPOSED NORTHERN LIMIT FOR THIS SPECIES, HAVE BEEN COMPARABLE TO THOSE OBTAINED IN THE LARGE HEVEA PLANTATIONS OF THE ORIENT WHERE PRACTICALLY ALL THE COMMERCIAL SUPPLIES OF RAW RUBBER ARE PRODUCED.

### Understanding Varietal Differences Essential for Effective Utilization

The great variety of problems under investigation in the Bureau of Plant Industry renders even a comprehensive summary of its activities impracticable in the space of a short paper, accordingly only a few of the activities that lend themselves to brief description have been summarized in order to indicate the general plan and purpose of the Bureau. Modifications of the plans described are followed in other research activities that range all the way from preparing detailed instructions for the benefit of county agents or others directly interested in applying improved methods of crop production to the more difficult and more time-consuming fundamental researches of genetics, plant physiology and plant pathology, upon which the more practical improvements in crop production are eventually developed. It is these subjects, for example, that established that for many products the older ideas of cold storage are incorrect, and that different products require entirely different treatment for their handling either prior to transportation or while in storage; also determining what varieties of fruit or vegetables are best adapted for canning or freezing and what varieties are more satisfactory to be utilized while in fresh condition.

National progress in agriculture through intelligent appreciation of existing facts and through the development of new ideas directly or indirectly related to crop production and plant growth has been the underlying purpose of the Bureau. Some of its activities have accordingly dealt more with general agricultural efficiency than with crop handling—for example, the organization of farm-management studies, now a branch of the Bureau of Agricultural Economics; the employment of local agricultural advisers of farm demonstration agents, now enlarged into the Smith-Lever extension, States and Federal Government cooperating; studies of rural organization and systems of agricultural marketing, later organized as the Bureau of Markets and now a part of the Bureau of Agricultural Economics; all these began as offices or branches of the Bureau of Plant Industry and developed until their size or relation to other branches of the department rendered their transfer expedient.

In general, the bureau carries on a very considerable portion of its activities in intimate cooperation with the scientific people of the state agricultural experiment stations and serves as a clearing house for the exchange of ideas relating to the problems of crop production between the different members of the state experiment stations and research men of the Department and also between the different crop producing industries and the county agents.

# THE WORK OF THE NATIONAL BUREAU OF STANDARDS IN CHEMISTRY AND METALLURGY

By Dr. EDWARD W. WASHBURN

CHIEF CHEMIST, NATIONAL BUREAU OF STANDARDS, U. S. DEPARTMENT OF COMMERCE

## CHEMISTRY

THE chemical work of the Bureau of Standards is at present administered under several different divisions, as shown by the following organization chart:

ADMINISTRATIVE ORGANIZATION OF THE CHEMICAL WORK OF THE BUREAU OF STANDARDS

The Division of Chemistry, E. W. Washburn, chief; P. H. Walker, assistant chief.
- (1) Physical chemistry, E. W. Washburn.
- (2) Paints, varnishes and other organic protective coatings, P. H. Walker.
- (3) Detergents, cements and miscellaneous materials, F. W. Smither.
- (4) Organic chemistry, C. E. Waters.
- (5) Metal and ore analysis, standard samples, G. E. F. Lundell.
- (6) Chemical reagents and the platinum metals, E. Wichers.
- (7) Electroplating, W. Blum.
- (8) Gas chemistry, E. R. Weaver.

The Optics Division, C. A. Skinner, chief. Sugar chemistry and the chemistry of photography.

The Electrical Division, E. C. Crittenden, chief. Electrochemistry and the chemistry of underground corrosion.

The Division of Organic and Fibrous Materials, W. E. Emley, chief. Rubber, textiles, paper, leather and farm wastes.

The Division of Clay and Silicate Products,[1] P. H. Bates, chief. Ceramic chemistry.

The Metallurgy Division, H. S. Rawdon, chief. The chemistry of metals and alloys.

The Heat and Power Division, H. C. Dickinson, chief. Thermodynamics and petroleum chemistry.[1]

The Chemistry Division was organized as a separate division in 1903 under the direction of Dr. W. A. Noyes as chief chemist. Under Dr. Noyes' direction, a number of noteworthy investigations in the field of atomic weights of the elements were completed and published. Dr. Noyes resigned in 1907 to become head of the Chemical Department at the University of Illinois and was succeeded by Dr. W. F. Hillebrand. Dr. Hillebrand's administration was characterized by an intensive program of research in the improvement of methods of quantitative analysis, the results of which are to-day represented by numerous contributions to the literature, by a scholarly treatise on "Quantitative Analysis" under the joint authorship of Hillebrand and Lundell, by a highly trained personnel, and by the establishment of the Bureau's set of standard samples for analysis and testing. These certified samples now number 100 and have a world-wide distribution. (See Fig. 1). The Chemistry Division is organized in sections, as shown above.

The chemical work of the Bureau is of two types: (1) routine analysis and testing, and (2) research.

The analysis and testing work is confined almost entirely to materials purchased by various branches of the government and is for the purpose of ascertaining whether manufacturers' products meet the government specifications. The testing work of the Chemistry Division is under the immediate supervision of P. H. Walker, assistant chief of the division, and its volume is so great that it occupies the full time of the larger part of the personnel. During

[1] The chemical work of this division will be discussed in a later paper of this series.

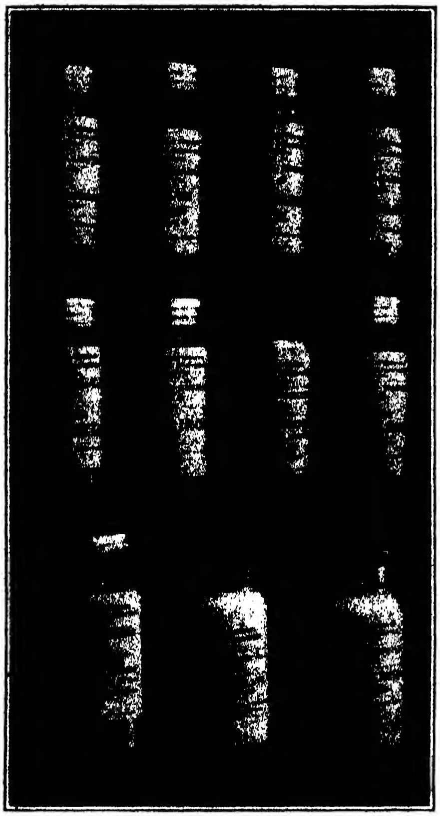


FIG. 1. PACKAGES OF STANDARD SAMPLES

CERTIFIED AS TO EXACT CHEMICAL COMPOSITION OR AS TO ONE OR MORE PHYSICAL PROPERTIES. 100 DIFFERENT SAMPLES ARE AVAILABLE FOR DISTRIBUTION. THE COMPLETE LIST, WITH PRICES, CAN BE OBTAINED BY APPLICATION TO THE BUREAU.

the fiscal year 1931–32, 16,059 different samples of material or products were tested.

Research work is carried on in each of the sections of the Bureau referred to above and covers a great variety of topics, only a few of which can be mentioned.

With the cooperation of the American Petroleum Institute the Chemistry Division has been working during the last five years on the problem of the constitution of petroleum, in particular the problem of separating it into its constituent hydrocarbons and identifying these hydrocarbons. To date thirty-two different hydrocarbons have been isolated, chiefly by purely physical methods, comprising distillation (See Fig. 2), crystallization and extraction. The results of this work have been published in twenty-five papers.

Other current research work in phys-

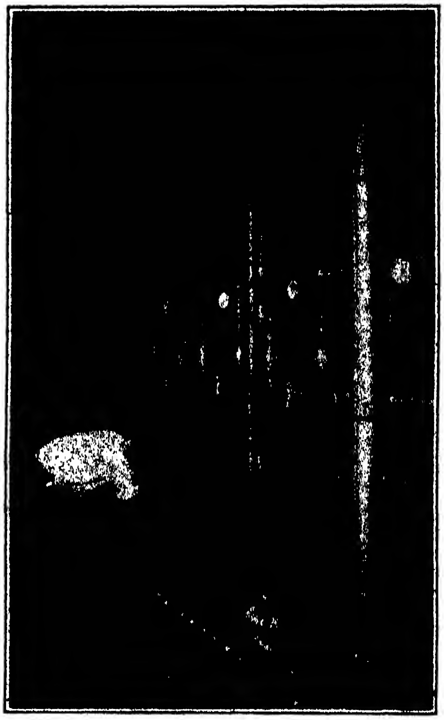


FIG. 2. SCENE IN THE DISTILLATION LABORATORY

SHOWING A BANK OF STILLS WITH TALL FRACTIONATION COLUMNS. THE COLUMN HEIGHTS VARY FROM TWO FEET TO THIRTY-FIVE FEET AND INCLUDE THE BUBBLE-CAP AND PACKED COLUMN TYPES. ALL STILLS ARE OF GLASS WITHOUT JOINTS AND ARE PROVIDED WITH MEANS FOR CONTROLLING THE TEMPERATURE, THE PRESSURE, THE REFLUX RATIO AND THE NATURE OF THE ATMOSPHERE WITHIN THE STILL. THE DISTILLATE PASSES CONTINUOUSLY THROUGH A SMALL COTTRELL BOILER WHICH SHOWS THE TRUE BOILING POINT OF EACH FRACTION COLLECTED.

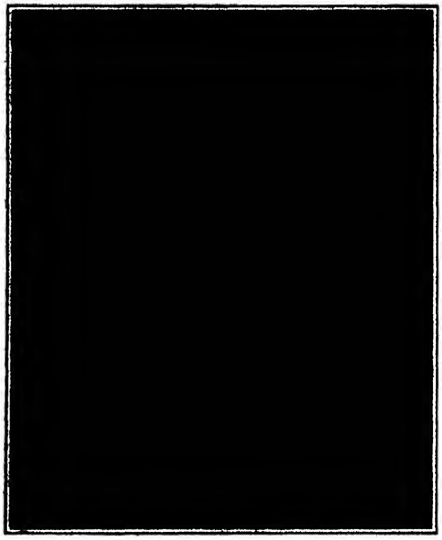


FIG. 3. CRYSTALS OF RUBBER

PHOTOGRAPHED BETWEEN CROSSED NICOLS, MAGNIFICATION 200× (AND 500×), TEMPERATURE −60° F. THESE CRYSTALS MELT AT 50° F. THEY ARE OBTAINED BY COOLING A DILUTE ETHEREAL SOLUTION OF PURIFIED RUBBER.

ical chemistry includes the accurate determination of the heats of chemical reactions, phase equilibrium data at high temperatures, and the preparation and

FIG. 4. THE ELECTROPLATING LABORATORY

SHOWING THE GENERATOR, THE ELECTROPLATING BATHS AND EQUIPMENT FOR CARRYING OFF FUMES.

properties of the isotopes of hydrogen and oxygen.

In organic chemistry the problem of the chemical nature of rubber is being systematically attacked and for the first time it has been found possible to crystallize the rubber hydrocarbon (see Fig. 3) and thus probably to separate it into chemical individuals whose properties and composition can be determined.

In general analytical chemistry, the research work is devoted to the development and improvement of analytical methods to meet the new situations which constantly arise through the appearance of new alloys and other products and the increased demands for more accurate chemical control of industrial processes. New types of standard samples must also be created from time to time to meet the changing needs of industry.

In electrochemistry the emphasis is largely upon the scientific and technical problems encountered in the electroplating of the various metals. In particular a series of noteworthy contributions has been made to the problems connected with chromium plating (see Fig. 4) and to the development of new uses for this extremely hard and permanent protective coating.

The section on the chemistry of the platinum metals is gradually bringing to completion a systematic scheme for the quantitative analysis of mixtures containing any or all of these six metals and has recently published a new determination of the atomic weight of osmium (see Fig. 5).

The gas chemistry section devotes a large part of its efforts to the development of the principles of design and testing of gas burners for domestic and industrial appliances to the end that these burners shall function efficiently under various conditions of service and without danger of producing the deadly

carbon monoxide gas (see Fig. 6). In this work the section is also closely associated with the public utility commissions of the states in the development of service standards.

In addition to its own research work, the Chemistry Division assists in the work of many of the other divisions of the Bureau through the analysis of materials and by the preparation of pure substances.

The Polarimetry Section of the Optics Division conducts work incidental to assisting the Treasury Department in the maintenance and operation of its customs laboratories. The bulk of this work is in connection with the testing of raw sugars and molasses for purposes of appraisal under the provisions of the Tariff Act. The bureau also acts as referee in disputes between buyers and sellers of molasses and other sugar products.

The Bureau's work on the preparation of exceedingly pure sucrose brought to light the existence of an error in the scale of the saccharimeter, the correction of which has led to an increase of over $200,000 annually in the amount of import duty collected upon the raw sugar entering the country.

In addition to the analytical work referred to above, the Polarimetry Section has contributed much to the world's knowledge of the chemistry of the sugars and related compounds. Its work has a two-fold purpose, first, to find more efficient ways of preparing and handling these carbohydrates, and second, to learn their chemical and physical properties as well as to obtain an insight into their molecular structures. That such studies may result in applications of extreme importance in our every-day economic life is evidenced by the extraordinarily rapid development of the corn sugar (dextrose) industry immediately after this Bureau demonstrated that dextrose, through proper handling, could readily be obtained on a commercial scale in a crystalline state in a general way analogous to that of ordinary cane sugar.

For many years the Bureau has found much of interest in the study of levulose, the sweetest of all the sugars, the most important one occurring in honey, and which constitutes 50 per cent. of the inversion products of our ordinary cane or beet sugar. In addition to being perhaps the most wholesome of all the sugars and possibly even considerably more assimilable by diabetics than ordinary sugar, it may be produced from a crop which is easily grown in almost all sections of this country, namely, the Jerusalem artichoke. For a long time a knowledge of the peculiarities of this

FIG. 5. APPARATUS USED IN THE DETERMINATION OF OSMIUM

THE OSMIUM SOLUTION ACIDIFIED WITH NITRIC ACID IS HEATED IN THE FLASK ON THE LEFT. THE VOLATILE $OsO_4$ IS DRIVEN OUT AND ABSORBED IN $HCl$ SATURATED WITH $SO_2$ IN THE THREE ABSORPTION FLASKS, WHERE IT IS OBTAINED AS THE COMPOUND $H_2OsCl_6$.

sugar was limited by the difficulty of preparing crystalline derivatives which could be purified and studied. Gradually, however, many types of derivatives have been prepared and studied. One of the most important, at least from the standpoint of the preparation of the sugar, is a compound formed between levulose and lime which, being almost insoluble, serves to separate the levulose from the impurities which accompany it

FIG. 6. ALTITUDE CHAMBER

WITH EQUIPMENT FOR TESTING THE BEHAVIOR OF GAS APPLIANCES UNDER CONDITIONS WHICH PREVAIL IN MOUNTAINOUS REGIONS.

in the plant juices and which retard its crystallization. A method of preparation based upon this derivative, and taking into account the chemical and physico-chemical properties of the levulose as previously determined, has been perfected on a semi-commercial scale, using apparatus capable of handling approximately one half ton of sugar per day (see Fig. 7).

Particular attention has been directed to the preparation of the aldonic acids. These substances are the simplest oxidation products of certain sugars, such as dextrose, xylose and lactose. One possible practical application of these substances is in the removal of boiler scale. A method of preparing these sugar acids at a reasonable cost has been developed and a Public Service Patent taken out to prevent it from being monopolized by private interests.

A large number of scientific papers dealing with the Bureau's discoveries in the realm of the rare sugars have been published in recent years.

The work of the Photographic Emulsion Laboratory, also in the Optics Division, may be described as the application of physical chemistry to problems of photographic sensitivity. Experimental emulsions are prepared under chemical control, the use of the silver electrode for this purpose having been developed in this laboratory. Special attention has been given to color sensitization.

The chemical work of the Division of Organic and Fibrous Materials has been directed chiefly towards the application of science to industry. Occasionally, however, it has been necessary to make excursions into the realms of pure science in order to obtain needed facts, as, for example, the molecular structure of collagen and the electrophoretic behavior of silk and wool.

Organic chemistry does not have a system of quantitative analysis which is generally applicable. Each problem is considered separately, and the methods adopted are subjected to continuous study and revision. The Bureau's method of analysis of wool-cotton mixtures has been given official standing by the Federal Trade Commission, and its method for estimating the amount of tin in weighted silk has been generally accepted by the industry. Extra refinements are sometimes called for, as in the case of cloth for rubberizing, which must

contain less than 0.001 per cent. of copper or 0.0005 of manganese.

The natural deterioration of organic materials is accompanied by chemical changes. Quantitative estimation of the end products affords a means of following the progress of the reactions, and of determining the values of accelerated aging tests. Thus the alpha cellulose content and copper number of paper, before and after accelerated aging, give information of value in predicting the probable life of the paper. The quantity of water-soluble nitrogen compounds which have been produced by hydrolysis of hide substance is dependent upon the past history of a piece of leather.

Acidity is an important cause of natural deterioration. It may occur as a result of the manufacturing process, or as sulphur compounds absorbed from the air. Its deleterious effect on cotton, paper and leather has been studied. For this purpose it has been necessary to develop methods for measuring minute quantities of sulphur dioxide and trioxide in these materials, and to investigate the effects of ferric iron and of sunlight in analyzing the oxidation of the dioxide to the trioxide. In the study of such wastes as cornstalks and

FIG. 7. LEVULOSE EXPERIMENTAL FACTORY

SHOWING FILTER PRESSES, GRANULATOR, EVAPORATORS AND CRYSTALLIZERS. JERUSALEM ARTICHOKE TUBERS ARE SLICED, EXTRACTED IN A DIFFUSION BATTERY, THE JUICE HYDROLYZED WITH ACID, NEUTRALIZED, CALCIUM LEVULATE PRECIPITATED, FILTERED OFF, TREATED WITH $CO_2$ GAS, AND THE PURE LEVULOSE LIQUOR CLARIFIED BY FILTRATION AND EVAPORATED TO CRYSTALLIZE THE LEVULOSE WHICH IS OBTAINED AS A BEAUTIFUL WHITE PRODUCT WITH A DELICIOUS TASTE—THE SWEETEST OF ALL THE SUGARS.

FIG. 8. SPRING BALANCE

WITH SPRING OF SILICA-GLASS FIBER, FOR DETERMINING ADSORPTION AND DESORPTION BEHAVIOR OF FIBROUS MATERIALS. THE MATERIAL TO BE STUDIED IS SUSPENDED FROM THE HOOK AND THE PRESSURE OF THE WATER VAPOR IS CONTROLLED THROUGH THE OPENING, E, WITH THE AID OF A VACUUM PUMP.

straw, complete electrometric titration curves are necessary to identify the various organic acids which may be present.

The water content of an organic material varies with the atmospheric humidity, and there is a corresponding important variation in the physical properties of the material. Practically, water is estimated by drying under certain empirical conditions. But one can never be sure under the given conditions, either that all of the water is removed, or that some of the loss does not consist of volatile material other than water. This question is therefore being studied by means of complete absorption-desorption curves (see Fig. 8).

Cotton seed linters, peanut shells, corncobs and similar wastes contain upwards of 25 per cent. of xylose. A semicommercial plant has been built to extract this xylose in pure crystalline form, and several tons have been made. It is believed that the information obtained in this work will ultimately become the foundation of a new chemical industry.

METALLURGY

A Division of Metallurgy was established at the Bureau of Standards in 1913 under the direction of the late Dr. George K. Burgess. Under his able leadership the division grew into substantially its present form. It is housed in a building constructed to meet its special needs and at present has a staff of 44 employees. When Dr. Burgess was appointed director of the Bureau in 1923, he was succeeded by H. W. Gillett as chief of the division. Dr. Gillett resigned in 1929 to become director of the Battelle Memorial Institute and was succeeded by H. S. Rawdon, the present chief of the division. The present organization of the division comprises the following sections:

(1) Optical metallurgy. D. J. McAdam, Jr.

(2) Thermal metallurgy. L. Jordan.

(3) Mechanical metallurgy. W. H. Swanger.

(4) Chemical metallurgy. J. G. Thompson.

(5) Experimental foundry. C. M. Saeger.

Metallurgy is most properly defined as "the art of extracting metals from their ores and of fitting them for practical use." The second part of the definition is just as important as the first and, in fact, most of the striking advances that serve to characterize "modern metallurgy," as distinguished from metallurgy of former days, have been made along this line.

Metallography, the study of the structure of metals, macroscopic, microscopic, and atomic, and its correlation with the observed physical properties, plays an exceedingly important part in modern metallurgical study. Likewise does the physical chemistry of mixed metals, whereby the rationale of alloy-formation has been put on a sound basis. The changes in the structure and properties of metals with temperature and the control of these changes form the basis of modern heat treatment. The plastic flow of metals under stress underlies the mechanical working of metals by rolling, forging, drawing, swaging, extrusion and the like. (See Figs. 9 and 10). It is with this general aspect of the subject of metallurgy which has been aptly called "physical metallurgy," to distinguish it from "chemical or process metallurgy," which relates to the recovery of metals from their ores, that the metallurgical work of the Bureau of Standards is almost entirely concerned.

An outstanding example of the successful application of the metallographic method in an industrial way came as a result of the pioneer work of the Bureau on duralumin a number of years ago. The explanation advanced for the "spontaneous" changes in hardness and strength which characterize this light aluminum alloy has formed the basis of numerous subsequent developments of alloys which respond to "precipitation hardening." In particular, many non-ferrous alloys can be hardened by heat treatment—a development entirely unsuspected on the basis of the older conventional ideas of metallurgy and attributable to the Bureau's metallographic study of the duralumin problem.

Duralumin has not always given satisfaction in service, however, as a structural material. Instances have been noted in which it has become weak and very brittle in use. Extensive laboratory study at the Bureau of Standards, supplemented by exposure tests to the weather extending over a period of five years, have served to show definitely, however, the conditions responsible for the undesirable and erratic loss of strength and also how this change can be prevented. Duralumin can now confidently be regarded as a reliable material for engineering structural purposes for most conditions.

As part of this work many proposed means for protecting duralumin structures were studied. The results have demonstrated conclusively the usefulness

FIG 9. ONE OF THE ROLLING MILLS AVAILABLE FOR STUDYING THE MECHANICAL WORKING OF METALS. A BENCH FOR WIRE-DRAWING IS PARTIALLY SHOWN IN THE BACKGROUND.

FIG. 10. HIGH TEMPERATURE TESTING EQUIPMENT

BY MEANS OF EQUIPMENT OF THIS KIND, THE TENSILE PROPERTIES OF METALS AT HIGH TEMPERATURES ARE STUDIED, ESPECIALLY THEIR TENDENCY TO "CREEP" UNDER LOAD. THE TEST OF A MATERIAL MAY BE OF SEVERAL MONTHS' DURATION.

FIG. 11. ANALYTICAL TRAIN

USED IN THE DETERMINATION OF "GASES" IN METALS. OXYGEN, HYDROGEN AND NITROGEN ARE DETERMINED IN THE SAMPLE WHICH IS MELTED IN THE HIGH-FREQUENCY INDUCTION FURNACE AT THE EXTREME RIGHT. THE EVACUATION OF THE TRAIN IS ACCOMPLISHED BY MEANS OF THE MERCURY DIFFUSION PUMP SHOWN.

of the anodic-oxidation treatment and a new method for carrying out this treatment has been recently developed for the Navy Department's use. Results obtained with duralumin coated with pure aluminum were so encouraging that the commercial development of "Al-clad" duralumin—the most dependable of all of the high-strength light alloys for structural purposes—followed, and ranks as one of the high spots in development of the aluminum-alloy industry.

"Gases in metals" has been made the scapegoat by many metallurgists for any and every unsatisfactory characteristic of metals not readily explainable otherwise. Without question many obscure characteristics of metals, such as the "body" or quality of tool steels, the abnormal behavior of certain steels when carburized, the changes in the properties of low-carbon steels on aging, etc., are intimately related to oxides and perhaps to other "gases" within the metal.

In view of the industrial importance of the problem, considerable time has been spent at the Bureau of Standards in the development of analytical methods for "gases" in steel. (See Fig. 11). The method depending upon the recovery of the gases evolved upon fusion of the metal *in vacuo,* which was perfected, is now quite generally used by all workers in this field. The study of the so-called "abnormality" of steels showed that the deoxidation treatment was largely responsible for the conditions, as it was also for the inferior properties of many steel castings.

An allied study is the attempt now in progress to prepare iron of very high purity. The properties of *pure* iron, the basis of all steels, are almost unknown, since various indeterminate amounts of "gases" are present in all "pure" irons previously prepared. The present method, depending upon large-scale chemical operations of precipitation, reduction, etc., rather than upon electrodeposition, or deoxidation in the molten stage, promises to give material exceeding in purity any previously described "pure iron." Similar work on pure nickel has already been done and published.

Of all metallurgical shop operations, that of casting, which has been practised from time immemorial by rule-of-thumb methods, is perhaps the most fertile field for technical study and improvement. (See Fig. 12). The Bureau's studies of foundry sands have aided very materially along this line. Marked advances are being made in this subject whereby the purchase, use and "control" of foundry sands are being put upon a sound technical basis. A good beginning has been made in the study of the factors upon which successful casting operations depend, such as the determination of the "running" properties of a metal cast in a foundry mold, and the distribution of the shrinkage of a metal during casting as related to the liquid phase, the period of solidification and the solid phase.

An outstanding foundry accomplishment is the development of a rubber binder for sand cores. Cores can be made by this means which require no preliminary baking and which disintegrate after they have served their purpose, thus facilitating their removal from the casting.

The deterioration of metal parts in service can usually be traced to one or more of the following factors: wear, corrosion and fatigue. These three form the subject of a number of the metallurgical researches now in progress. One of the outstanding projects under way is the study of steel bridge-cable wire. Wire, especially in the form of cables, is an important structural material for bridge and other construction. The attempt a few years ago to utilize modern methods of heat treatment of the time-honored

FIG. 12. ELECTRIC FURNACES IN THE EXPERIMENTAL FOUNDRY

FOR THE MELTING OF METALS. THE ONE IN USE IS A TILTING HIGH-FREQUENCY INDUCTION FURNACE.

cold drawing process in the preparation of such wire for suspension bridge construction ended in disastrous failure and the dismantling of two bridges. Several very important facts bearing on the subject have already been disclosed. A somewhat analogous problem is that of rail steel, the propensity of which to failure in service by the development of internal fissures constitutes a serious liability in the maintenance of the railroad tracks. The Bureau's work has shown that the steel possesses low ductility at elevated temperature over a considerable range of temperature. Internal-shrinkage cracks form on cooling. Several processes, based upon this work for controlling and remedying the situation, are now coming into practical use in the steel mill.

The problem of deterioration by wear is extremely important in the industrial use of metals. The fundamental factors involved in wear-resistance are receiving much study. Oxidation or corrosion during wear is an important factor. In the field of bearing metals much has been accomplished in determining the characteristic properties of bearing alloys at service temperatures and the development of alloys which will serve to conserve tin—a strategic material—if the necessity should arise. This is distinctly a governmental research.

Until relatively recently, the heat treatment of steel has been strictly a rule-of-thumb procedure. The Bureau's work on the quenching of metals, the importance of which was recognized by the American Society for Steel Treating in the medal bestowed upon the investigator in charge, has aided in no small degree in raising the status of this subject.

In addition to investigative work, the Bureau is called upon by other departments for metallurgical testing work. Very little of this can be classed as routine, however; nearly every one is a minor research such as the investigation of failure of metals in service.

The results of the Bureau's researches in metallurgy have been published in some 460 different papers.

# CANYONS BENEATH THE SEAS

By Dr. FRANCIS P. SHEPARD
UNIVERSITY OF ILLINOIS

HALF a century has elapsed since Captain Lindenkohl discovered that the soundings of the ocean bottom off New York harbor indicated a submarine continuation of the Hudson River valley. Examination of the charts from other parts of the world showed similar features, and as charting became more complete it was found that deep submarine canyons were incised into the ocean floor in numerous places off all the continents. Many of these submarine depressions were found to extend to depths of over a mile and to have steep walls thousands of feet high.

About thirty years ago the subject of submarine canyons was discussed in many scientific articles. The American geologist A. C. Spencer and the British geologist Edward Hull drew elaborate maps showing continuations of the great river valleys of Europe and America out into the depths of the Atlantic.[1] They concluded that the valleys were cut by rivers at a time when the continents were elevated thousands of feet above their present levels. They considered that this uplift produced a change in temperature sufficient to bring on the great ice sheets of the glacial period. One fatal weakness to the last assumption developed when the evidence became more and more convincing that the glacial period included at least four and perhaps five epochs of glaciation separated by times of mild climate. To have maintained the idea of elevation as a cause of climatic changes it would have been necessary to assume a series of uplifts and sinkings of great magnitude within what is considered by geologists to be a very short period. The weight of evidence suggesting that large changes of the land surfaces have been very slow and that the continents have been relatively stable in relation to the ocean basins has caused most geologists to disregard this evidence of elevation, and for some time the submarine valleys have been relegated to the oblivion which often absorbs the phenomena which do not appear to fit into current hypotheses.

In the old surveys the soundings in submarine valleys were generally so diffuse and so inaccurately coordinated that an investigator had little means of determining the form of the features.[2] Recently the United States Coast Survey vessels have been equipped with devices which readily obtain closely spaced soundings, even in deep water, locating these soundings with great accuracy, even well beyond sight of land. The soundings are taken by the accurate measurement of the time between the sending of a sound impulse from the hull of the ship and the receiving of an echo of this sound, an interval which is proportionate to the distance from the ship to the bottom. The locations are determined by a similar method in which sound is developed by bombs, and the distance between the survey ship

[1] A. C. Spencer, "Submarine Valleys off the American Coast," *Bull. Geol. Soc. Am.*, 14: 208, 1903; Ed. Hull, "Sub-Oceanic Physiography of North Atlantic," London, E. Stanford.

[2] Descriptions of the canyons by Spencer and others were far more detailed than the data warranted. The mention of a waterfall in the course of the submarine valley of the Hudson, for example, was due to a lack of understanding of the limitations of surveying out of sight of land.

and two vessels anchored in established positions is found by means of a chronograph and wireless relays. Many of the submarine valleys off the west coast of the United States have been surveyed, using these new methods and in the summer of 1932 a series of tremendous canyons was discovered and surveyed off the coast of New England. This recent information, taken in conjunction with the earlier work, makes it possible to pursue a more promising investigation into the mysteries of the sea floor canyons.

### Comparison with Land Canyons

The valleys of the ocean bottom have proven to be of a size and depth quite comparable with our Western canyons and may even match in vastness the Grand Canyon of the Colorado. A section made from wire soundings across the deepest submarine canyon so far discovered and a section across the Grand Canyon, using the same number of observations and the same spacing, will illustrate this comparison (Fig. 1, c and d). The insignificance of the Yellowstone Canyon compared to one of the canyons off the New England coast is also striking (Fig. 1, a and b). Whether the submarine canyons contain anything comparable to the remarkable terraces and buttes of the Grand Canyon can not be told as yet, since even the echo-sounding profiles give only a generalized section because echoes come from the nearest good reflecting surfaces rather than from points directly beneath the vessel. However, there are some indications of highly irregular sections across certain of the canyons off the west coast.

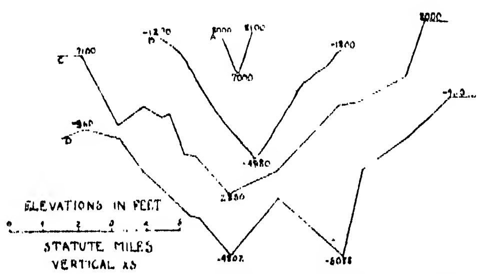



FIG. 1. A COMPARISON OF THE CROSS SECTIONAL VIEWS OF LAND AND SUBMARINE CANYONS.

A REPRESENTS THE YELLOWSTONE CANYON. B IS FROM A RECENTLY DISCOVERED CANYON OFF THE NEW ENGLAND COAST. C AND D REPRESENT THE GRAND CANYON AND A CANYON OFF THE COAST OF NORTHERN CALIFORNIA. THE SCALE IS THE SAME FOR EACH. THE NUMBER OF OBSERVATIONS ON WHICH C IS BASED WAS MADE TO CORRESPOND TO THE NUMBER AVAILABLE FOR D.

### Origin of the Submarine Canyons

Despite the absence of minute details in the present surveys of submarine canyons, there appears to be enough general information to allow some tentative conclusions to be drawn concerning their origin. In the past several theories have been presented to account for them. Besides the idea that they were the result of river cutting in a temporarily emergent sea bottom, they have been attributed to faulting or rifting of the earth's crust, to powerful submarine currents, and to the collapse of suboceanic caves.[3] However, the character of the canyons is difficult to explain in any of these ways.

*Faulting and Rifting:* Deep valleys on land have been formed by the slow down-sinking of blocks of the earth's crust, as in the case of the Jordan-Dead Sea Valley in Palestine and Death Valley in California. Other valleys have been attributed by some geologists to the pulling apart of the earth's crust, as, for example, the Rift Valleys of East Africa.[4] Valleys produced by

[3] For a more complete discussion of these ideas than will be presented here the reader may consult an article by the writer entitled "Submarine Valleys" (*Geographic Review*, January, 1933).

[4] These valleys may be due to simple downfaulting, an opinion held by other geologists.

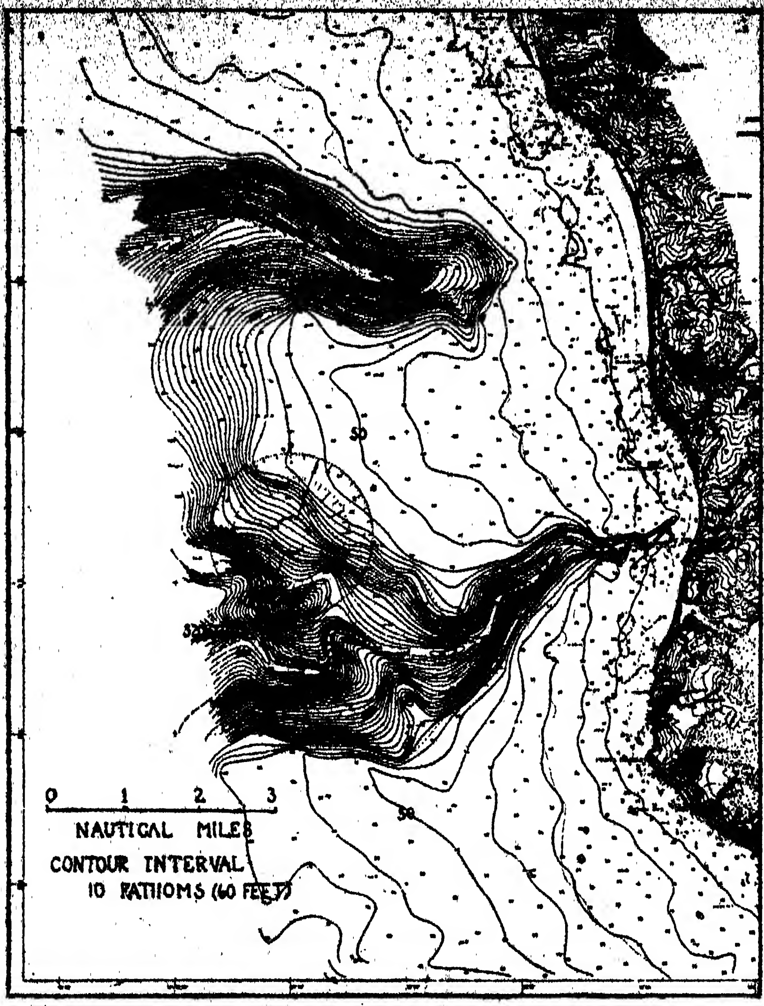



FIG. 2. TWO CANYONS OFF THE COAST OF CALIFORNIA NEAR CAPE MENDOCINO.

The shape of the canyons is expressed in contours below sea-level. These contours connect points of equal depth, just as land contours connect points of equal elevation. Accordingly, valleys are shown by the bending of the contours towards the coast and the steepness of valley slope is shown by the spacing of the contours, a steep slope having close spacing. The figures represent fathoms. Contouring by the late Professor H. H. Robinson from some charts kindly furnished to the writer by Mrs. Mabel Robinson.

either of these processes have some characteristic features of topography, such as straight sides, steep walls, broad relatively flat bases, and in most cases uplifted irregular blocks adjacent to them. The typical submarine valleys, on the other hand, have curved patterns, V-shaped bases, and in their inner por-

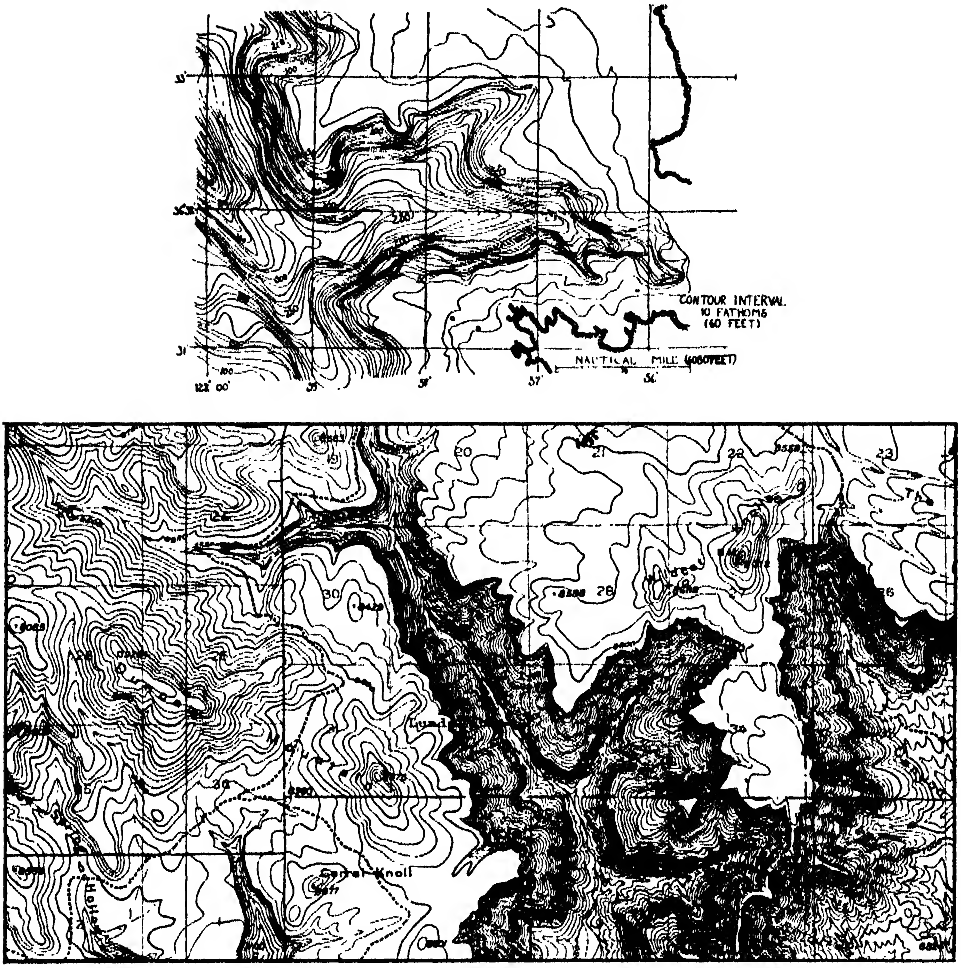



FIG. 3. ILLUSTRATING THE SIMILARITY OF THE CONTOURS IN A TYPICAL SUBMARINE VALLEY TO THOSE IN LAND CANYONS

APPROXIMATELY THE SAME CONTOUR INTERVAL IS SHOWN AND THE SAME SCALE. NOTE THE WAY IN WHICH THE TRIBUTARY VALLEYS ENTER THE MAIN IN BOTH CASES AND THE WAY THE VALLEYS SLOPE OUTWARD CONTINUOUSLY IN EACH CASE. UPPER; TAKEN FROM CARMEL BAY, CALIFORNIA. LOWER; FROM THE U. S. TOPOGRAPHIC SHEET, ACORD LAKES, UTAH. THE HEAVY CONTOURS ARE AT INTERVALS OF 250 FEET.

tions are flanked by the relatively even-floored continental shelves[5] (Figs. 2–4).

*Ocean Currents:* In some places the currents produced by the tides are sufficiently powerful to erode even rock bottom so that it is conceivable that they might produce submarine canyons. However, the strong tidal currents are confined, so far as we know, to narrow inlets along the coasts and are probably quite powerless out on the open continental shelves where the deep canyons have been discovered. The finding of

[5] Continental shelves are the shallow platforms which extend seaward with gentle slopes off most of the coasts of the world.

muddy bottom in many of the canyons and sandy bottom along the adjacent continental shelves suggests that the conditions in these canyons are quieter than on the shelves or the fine sediment could not come to rest. Some observations by fishermen appear to check this suggestion of quiet conditions in the valley bottoms. Probably currents have little to do with valley formation, but this view should not be considered as final until more observations have been made.

*Collapse of Sub-oceanic Caves:* Underground water certainly does circulate to some extent beneath the margins of the ocean. This has been proven by the springs and wells of outlying islands and by the gushing out of fresh water into the ocean in shallow water near shore. In order to produce a submarine canyon by circulation of this water several conditions would be essential. A layer of soluble material would have to underlie insoluble, relatively impervious material and this layer would have to extend out almost at right angles to the coast. Water circulating in the soluble layer could emerge only at great depths in the continental slopes[6] during the formation of the cave. The cave roof would have to collapse along practically its entire length in order to produce a valley-like depression. Even under these ideal and almost impossible conditions only a relatively shallow valley could be formed, since caves never acquire great vertical dimensions, except around sink-holes. Furthermore, the soluble rocks favorable to the formation of caves do not exist on shore opposite most of the submarine valleys.

*River-cut Valleys:* There are a number of reasons for believing that the submarine valleys were cut by rivers. They are found directly off the mouths of many large rivers, such as the Indus, the Ganges, the Congo, the Niger, the Hudson, the Mississippi and the Columbia. In their inner portions they have the V-shaped transverse profiles which characterize the early stage of valley cutting by rivers in regions of high relief. They have the sinuous courses typical of river valleys and in some cases the dendritic (tree-like) pattern of a river valley system (Fig. 3). Also most of the valleys extend across the continental shelves and down the continental slopes in the direction which one would expect a river to take if the shelf and slopes were laid bare.

On the other hand, there appear to be objections to the idea of a fluvial origin for the valleys. The enormity of the uplift and sinking necessary, as stated above, is somewhat staggering to the imagination, especially since almost all the coasts of the world are involved. Many of the submarine canyons head near coasts which have no near-by land valleys. Also the drowning of a river valley system should produce large estuaries, like Chesapeake Bay, for example, but the submarine canyons are found off relatively straight stretches of coast. The nature of the continental shelves is especially hard to reconcile with the idea of major earth movements. These shelves have a remarkable tendency to terminate at depths varying from 300 to 500 feet, and the shelves adjacent to the submarine canyons do not form exceptions to this rule. Huge movements of the continental shelves in recent times should have destroyed this uniformity.

A lowering of the sea-level could have allowed the cutting of the valleys into the shelves and slopes beyond. This explanation removes some of the difficulty regarding the uniformity of shelf edge, but is open to equally serious objections. Since the valleys extend to depths of one or more miles, this hy-

[6] Continental slopes are the steep inclines which connect the gently sloping continental shelves with the deep ocean floors.

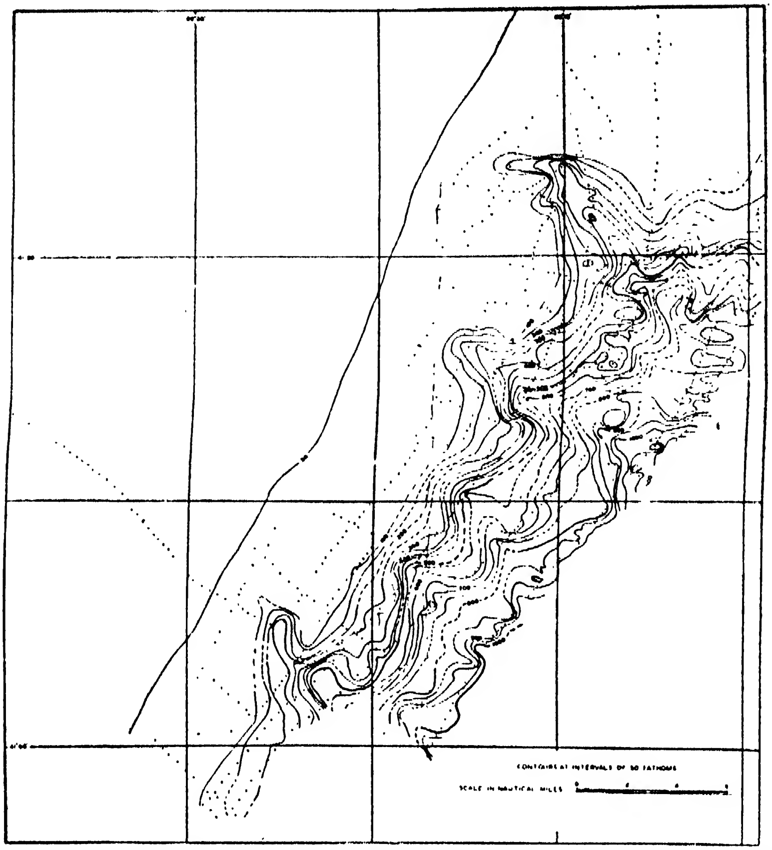


FIG. 4. SHOWING THE RECENTLY DISCOVERED CORSAIR GORGE OFF THE NEW ENGLAND COAST.

THERE IS REASON TO BELIEVE THAT THIS GORGE WAS REOPENED BY A LANDSLIDE AT THE TIME OF THE GRAND BANKS EARTHQUAKE. THE DOTS REPRESENT POSITIONS OF SOUNDINGS. THE SOURCE WAS FROM A 1930 AND 1931 SURVEY BY THE U. S. COAST SURVEY AND ADJUSTMENT OF THE SOUNDING LINES BY THE WRITER.

pothesis would imply the storing of about one half of all the ocean water during the valley-cutting stage. If stored on the lands as glaciers the ice would have had an average thickness of about 15 miles over the entire glaciated territory. This seems both impossible and incompatible with all the evidence. The alternative that the ocean bottom sank and then returned is a possibility, but it implies the sinking of all the ocean floors an average of one or more miles and their return to approximately the former elevation. It is almost inconceivable that the rock under the ocean basins could have been so displaced as to allow such movements, especially over such a short period as would seem to have been involved in the cutting of the steep-sided canyons.

*Landslides:* Several years of study of the phenomena of submarine canyons brought the writer to the impasse where all the hypotheses which had been suggested previously seemed hopelessly inadequate. Some new process seemed necessary to explain these amazing topographic features. An unusual sequence

of events suggested a clue to the identity of the unknown factor. In the fall of 1929 a world-shaking earthquake disturbed the ocean bottom to the southwest of the Grand Banks of Newfoundland. Submarine cables over a large area were broken in many places and a large tidal wave swept into the coast of Newfoundland and carried away many houses into the sea. A few days later Captain Boule, of the steamship *Transylvania*, reported that the outer continental shelf off the New England coast had been depressed during the earthquake. This report was thought doubtful at the time, but the next summer the United States Coast Survey started to make a new chart of Georges Bank and crossing the locality referred to by Captain Boule they found a new submarine valley called Corsair Gorge (Fig. 4). Evidence from liners employing echo-sounding devices has established the probability that this feature was either formed or enlarged at about the time of the earthquake. If this deep gorge were due to a sudden faulting action, it would have been of a size totally unknown on land and would have shaken the surrounding lands and made a record on the seismographs. Since there are no records of such action, the change must have been slow. On land great avalanches occur without producing seismic waves of important magnitudes and cause changes in the topography which are much more evident than are those accompanying earthquakes. Accordingly, it appeared probable that Corsair Gorge was a product of a large submarine landslide set off by the shaking transmitted from the Grand Banks earthquake. Additional soundings made in the outer portion of the canyon in 1931 revealed hummocky topography characteristic of landslide accumulations.

Here was a new suggestion which at first thought might have been considered as the entire cause of the submarine canyons. In many ways these great valleys are ideally located for such a process to operate. They are associated with the steep continental slopes which would give impetus to sliding. The sediments which have accumulated there are saturated with water, making them subject to slides, particularly in the case of the colloidal clays. Also numerous earthquakes originate along or near the base of the continental slopes and these would provide the motive power to start the sliding process.

A little reasoning, however, will show that landsliding is not an explanation which will account for the shape of the submarine canyons. If we assume that the outer portion of the continental shelf is a great mass of sediment washed out from the land and built out over the ocean floor, this sediment would be unstable and subject to slides, but the scars left by such slides should be lunate or cirque-like, such as those on land. If the shelf is underlain by rather weak rock, slides might occur, carrying masses of the rock down the slopes, but again the scars should be cirque-like. The submarine canyons differ in shape from almost all landslide scars known on the continents.

The situation is improved if we can assume that the valleys were formed long ago and were only reopened by landslides in recent times. If the valleys were cut by rivers many millions of years ago during times of great uplift and then submerged, there would have been time for the cutting of the continental shelves adjacent to the valleys producing the present accordant shelf relations. Also the shore line, greatly indented by the submergence, might have become straightened in the course of time. During these changes sediments would have been deposited in the submerged valleys and if no process had interfered, they would have been en-

tirely filled. However, this sediment fill must have contained much clay and silt, since the bottoms of the valleys were presumably at great depths where quiet conditions exist. Clay and silt, particularly if containing high percentages of colloids, are very subject to sliding. The continuous outward slope and the high gradients of the valley bottoms would also have produced good planes for sliding. It is conceivable that the valleys have been filled or partially filled many times, only to be reopened by landslides.

Some of the other features of the submarine valleys which were troublesome under the older hypotheses become understandable with this new combination hypothesis. Thus the close proximity of the valleys to deltas where sedimentation would eliminate them in short order is not surprising if they have been reopened very recently. In some places the bottoms of the valleys have been found to contain coarse gravel and fragments of rock have been collected from their sides.[7] Since the depths associated with these findings are considerable, only muddy fine-grained sediments or calcareous oozes could be carried there by ordinary processes at present. The coarser material and the rock bottom may have been the result of landslides which carried away the fine material of recent generation and exposed buried surfaces which may have been the product of subaerial conditions in the remote past. Also the hummocks and depressions within portions of the valleys which are revealed by the recent surveys are characteristic of landslide surfaces.

Landsliding may be a very active process on the ocean floor at the present time. Means of comparing old and new depths are not available except in a very few places,[8] but there are at least three cases where changes in the bottom of large magnitude seem highly probable. Besides Corsair Gorge, Sagami Bay in Japan and a place along the coast of Peru appear to have been subject to large landslides after earthquakes.[9] Also cable companies have frequently reported the burying of their cables by landslides as well as the severing of cables by the same process.

### The Crustal Movements

Since the landslide explanation involves the original cutting of the valleys by rivers, we are still confronted with the problem of the tremendous earth movements necessary to elevate the continental margins and then to depress the truncated land surface beneath the sea. If this had occurred recently there should be abundant evidence along the coasts, but according to the landslide explanation these gigantic movements may have been well back in the geological time scale, so that the traces may have been largely removed. If the uplifts of the various coasts were simultaneous the effect on rainfall in the interior must have been tremendous and the temperature of the elevated tract must have been greatly lowered. However, it is equally likely that the uplifts could have been at widely different times, producing much less worldwide climatic changes.

The character of the deformation

[7] The writer obtained samples of a limestone with quartz pebbles from the sides of a valley off New England in three different places, which makes it probable that these fragments were from a solid rock formation.

[8] In order to make this comparison there must be surveys at two different dates, each of which had an abundance of soundings well located. Slides only occur on or near the steep slopes and these slopes are generally well out from land where locations were very faulty on the old surveys.

[9] For discussion of this evidence see, "Landslide Modifications of Submarine Valleys," *Trans. Am. Geophysical Union* for 1932, pp. 226–230.

which would have produced such changes is difficult to imagine. It might have been in the nature of great upfaulting of blocks along the continental margins or possibly the entire continents were uplifted. According to Joly,[10] radioactivity produces periodic revolutions in the earth's surface causing the continents to rise and fall in relation to the ocean basins. Possibly something of this nature has happened. However, we need to make more of a study of the nature of the valleys before we go more deeply into such speculations.

### Suggestions for Future Research

Recently progress in the charting of submarine canyons has been made, but the present information leaves much to be desired. A series of echo soundings across a submarine depression gives only a generalized section. In order to determine whether these canyons have such features as terraces and buttes like the Grand Canyon and whether they show true landslide topography it will be necessary to have a network of soundings made by wire and very closely spaced. Such information is not of sufficient practical importance to warrant coastal surveys undertaking to obtain it. Owners of sizable yachts might find such an investigation an interesting game.

To make such a study buoys should be planted on the continental shelf at the margin of the valleys in order to obtain exact locations. Lines of soundings should then be run back and forth across the valleys, using wire-sounding machines. Plotting these soundings as they were made would show features of unusual interest which might call for more detailed study. Samples obtained from the bottom would greatly add to the value of the undertaking, and determining of the currents in the valley bottom might prove interesting.

[10] John Joly, "Surface History of the Earth," p. 94, 1925.

# THE DOMINANCE OF ECONOMICS OVER EUGENICS[1]

By Dr. H. J. MULLER

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It is now over fifty years since Francis Galton promulgated the doctrine of eugenics. It has become a highly popular subject for parlor talk and best sellers. Yet, aside from some sterilization of imbeciles, we are to-day further than ever from putting eugenic principles into actual operation.

That genetic imbeciles should be sterilized is of course unquestionable, but we should not delude ourselves concerning the importance of the benefits thereof. Following Haldane, we may recall the fact that if (as is commonly claimed but still very doubtful) most imbecility is due to the same recessive gene, then the sterilization of all imbeciles in every generation would not reduce their number to half until about ten generations had elapsed, and subsequent elimination would be even slower. And after all, actual imbecility represents only a very small part of the hereditary weaknesses which a rational genetic therapy would seek to reduce in frequency. Of these various genetic defects, imbecility is by no means the most onerous; firstly, because the imbeciles do not themselves suffer from the consciousness of their defect; secondly, because it is not inhumane to segregate them into institutions, where they constitute much less of an economic and psychological burden on their fellowmen than do many lesser defectives who must remain in the community at large, and thirdly, because, unlike some types who are psychologically abnormal by heredity but who may go about unrecognized as such, they have not the wits to do positive harm on any considerable scale.

The attack on imbecility was to have been only a first step. Yet eugenists (when they have not wandered off into the bogs of caste prejudice) have in the main stuck at that point. The major task of eugenics is not to get rid of this or that specified and highly conspicuous abnormality, such as total hereditary deafness or blindness, existing in relatively rare individuals who might conceivably be subjected, as a class, to outright sterilization. An individual's total genetic fitness (his biologically optimal rate of reproduction) is a complex resultant of manifold variable characteristics, that should be weighted, so far as possible, according to the potential value (+ or –) for society, of the genes by which they are determined. Thus genetic worth is a practically continuous variant, and there is no hard and fast line between the fit and the unfit, nor does relative fitness in the great

[1] This article is based upon an address given before the Third International Congress of Eugenics, in New York City, on August 23, 1932. The author desires to acknowledge that in some of the points herein presented, notably that of the lack of justification for the assumption made by most eugenists, that our present social stratification is positively correlated with genetic worth, he has been influenced by conversations held with Dr. Alexander Weinstein some fifteen years ago (see MS. of the latter, 1918). Some of the other points were expressed by the present author in a MS. of 1909 (address before the Peithologian Society of Columbia University). The attention of readers interested in the present subject may here be called to the symposium on "Heredity and Environment in Man," by Newman, Burks, Weinstein and Hogben, in *The American Naturalist*, May–June, 1933. This symposium was held at the joint meeting of Biological Societies affiliated with the Association for the Advancement of Science, at Atlantic City, December 30, 1932.

majority of individuals depend on one or a few pre-specified genes. It is to be expected, however, that occasional genes of greatly preponderant value will here and there occur, and it is in a general way true that the more advantageous these genes are, and the rarer they are, the greater is their weight, and hence the more important is what happens to them.[2] Now, eugenics requires that conditions be so ordered that the rate of reproduction in the population at large will be positively correlated with the total genetic fitness of the individuals, taken in the sense above stated. When we say that the vital thing, for the population at large, is a relatively low rate of multiplication of those who are, in general, genetically less well equipped, without a decrease in the total size of the population, it is therefore the same as when we say that there must be a relatively high multiplication rate of the better equipped germ plasm. Ideally, the rate should vary directly as total genetic fitness, all along the line, there being, from this point of view, no ultimate distinction between negative and positive eugenics. Since Galton's time, absolutely no headway has been made in realizing this major aim; in fact, it is widely claimed by eugenists themselves that just the opposite process is increasingly operative, despite their own preachments.

What is the reason for this contradiction? We might as well admit that the forces at work here are quite beyond the control of us as eugenists, in the society in which we live. For they are fundamental economic forces. The social direction of human evolution (as Kellicott aptly termed eugenics) can occur only under a socially directed economic system. Galton lived under circumstances and at a time in which we could scarcely expect him to have appreciated the principle, brought out by Marx, that the practises of mankind, in any age, are conditioned by the economic system and material technique existing in that age. He thought that they could be moulded willy-nilly, from without, into conformity with the abstractions of an idealist intellectual. But the organization of society to-day, based on the private ownership of large-scale means of production, is such as to make the primary motive of action, at least among the dominant section, the motive of private profit regardless of others' expense. This motive, operating in connection with our *de facto* socialized physical mechanism of production, works out in devious ways that are antagonistic to the welfare of the race as a whole, despite the fact that some of our modern philosophies, in a defense reaction, try to rationalize the two ends into harmony.

In the first place, it is undeniable that the profit system leaves little place for children. In general, they are not profitable investments: their cost is excessive, the dividends from them are uncertain, they are likely to depreciate in value, are practically non-transferable, and they do not mature soon enough. One child may be necessary for continuance of an estate, but each additional

[2] The potential value, or "weight," of a given gene in a given individual now existing may be regarded as the product, by multiplication, of two different factors. One of these is the amount of advantage (+ or −) to society (including of course the individual himself) which would on the average result from the possession of this gene by an individual. The second factor is the number of descendants who would come to possess derivatives of this very gene, if the latter became optimally multiplied (this is not to be confused with the number that would possess a gene of the very same kind, derived from other individuals now existing). It is necessarily true that the rarer a certain kind of useful gene now is, the greater is the amount of multiplication which any given representative of this kind of gene, now existing, could and (ideally) should undergo, and so the higher will the second factor concerned in the determination of its weight become.

one weakens it. For the great masses, who have no estates, each extra child commonly means more intensified slavery for the parents, and an additional unit of human unhappiness, in itself. And as the status of the middle class sinks, the parents hesitate to rear children with lesser privileges than they.

How much can eugenic considerations weigh in determining the actions of people under these conditions? To what extent will they lead people of greater genetic worth voluntarily to have four, five or even more children (remembering that more than three are usually necessary to a couple, if there is to be any increase at all)? Is it to be wondered at that a census of eugenists themselves has disclosed an appalling failure to reproduce themselves, despite the fact that they are maximally steeped in their own doctrines? Under the conditions that exist to-day, we know very well that it is a rare couple that has four or more children, except as a result of accident, ignorance or superstition, or under atypical conditions that represent disappearing survivals of an older system.

It is true that the universal dissemination of scientific birth control technique would tend to eliminate the production of unwanted children, and to this extent it would bring reproduction under the direction of reason. It is to be welcomed whole-heartedly, as a most important biological invention that increases the potential control of man over natural forces. It will help to fend off a part of the intolerable misery that would otherwise afflict innumerable individual cases, yet we must remember that the economic screws will eventually be forced down again as tightly as they can be anyhow, any relaxation of the pressure from beneath being responded to by a compensatory increase of pressure from above. That is, when the burden of family care diminishes, wages can be decreased still more, so that birth control provides no remedy for the faults of our economic system. Moreover, it must be admitted that birth control, by itself, would certainly not suffice to meet the major needs of eugenics. Not only is it illegitimate to assume that those now unenlightened, whose reproduction would be reduced by the further spread of birth control technique, are genetically inferior, in respect to the traits most valuable for a well-ordered society, but, in technically advanced countries like ours, in which the birth rate as a whole is low, the mere reduction in reproduction rate of any section of the population, uncompensated by an increase elsewhere, would be eugenically inadequate. Even more vital, from a biological standpoint, is an actual increase of those having the more valuable genes, and it is the obtaining of this increase that is prevented by economic pressure, and by social pressure having an economic basis.

In addition to the financial load involved in having children, we must consider the direct burden imposed on the mother. Do male eugenists suffer from the illusion that most intelligent women love to be pregnant and to endure not only the physical disabilities but also the shame and humiliation, and the difficulties of maintaining a job, that pregnancy involves in our society? That they love the frightful ordeal of childbirth, so seldom relieved by competent medical treatment? That they love to spend forty or fifty thousand hours washing diapers, getting up in the night, tending colic, stewing soups and milks, meeting in a city flat their little savages' requirements of safe outdoor activity and companionship, acting as a household drudge, and either abstaining from the life of the outer world entirely or else staggering under the double burden of a very inferior position outside and work in the home as well? It would be physically possible through organized

social services of various types, accompanied by a revolution in our attitude towards women, vastly to ameliorate these afflictions of the female sex, to reduce them, in fact, to the point where the compensations were greater than the disadvantages. But there is no particular profit in bettering the lot of a slave. Meanwhile, intelligent and self-respecting women, and those who value their husband's love, will use what means they may have to restrict the size of their family to a very low level indeed. And in this they will not be wrong. The eugenist, from his glass house, can not criticize them for this.

It is true that subsidies for children have been proposed by some eugenists as a remedy for this situation, but measures that would be really adequate are inconsistent both with the professed principles and with the actuating motives of the private-profit system, with its individualistic ideology. These proposals reveal a total lack of appreciation of the origin and the magnitude of the difficulties above referred to, and of the mechanism of operation and the limitations of our profit system. Within the framework of the latter we can not hope to obtain the wholesale redistribution of goods and services, the complete reorganization of practises and attitudes which alone would suffice to meet the situation confronting us. What is required is no mere individual prizes, doles or other charities, such as might (by a stretch of imagination) be conferred on some favored individuals, but a society consciously organized for the common good so as to assure every one economic plenty, a society meeting fully its obligations both towards the younger generation and towards the older generation who bear and rear the younger. All this presupposes public ownership of the means of production.

A second way in which our economic system acts to foil the true purposes of eugenics is by masking the genetic constitution of individuals and of vast groups through the gross inequalities of material and social environment which it imposes upon them. The investigations of Burks and of the Chicago school on the resemblance between the intelligence of foster children and their guardians, and Newman's converse findings concerning the considerable differences between the intelligence quotients of genetically identical twins who were reared apart, show clearly the important influence of environment as well as that of heredity upon intelligence as ordinarily measured. So too do the studies of Tallman and of Hermann and Hogben.

The latter group of studies revealed the fact that ordinary brothers or sisters (*i.e.*, those of different ages) are considerably less like one another, in their response to intelligence tests, than are brothers or sisters of the same age (non-identical twins), despite the fact that the purely hereditary differences must in both kinds of cases be of the same average magnitude. The greater amount of difference between ordinary brothers or sisters[3] must be due merely to those environmental factors which differentiate the same family at different periods. In Burks' cases, the usual differences between certain chosen, measured features of home environment alone, occurring between families of the type she studied (mainly middle class), caused an average difference of about 6 points in the child's "Intelligence Quotient" (on a scale in which 100 is the "normal" I.Q.). This agrees as closely as could be expected with Newman's data. The latter indicate that those I.Q. differences between identical twins reared apart, which were caused by their having been reared apart, are

[3] The amount in question had, in these series of observations, nearly the same value as the amount by which the differences between non-identical twins exceeded those between identical twins.

on the average of about the same magnitude (7± points) as those I.Q. differences between brothers or sisters, which were caused by their differences in heredity. To be sure, the hereditary differences between brothers or sisters average only about half as great as those between non-related individuals of a group. But in Newman's cases, as in Burks', the individuals compared were reared in what was in the main the same social class, so that the differences in environment were restricted also. Surely, the members of widely different social classes, such as Burks' mainly middle class people on the one hand, and white day laborers or Southern Negroes or Mexican immigrants, on the other hand, differ from one another, on the average, in respect to environmental advantages, by at least several times the average difference between two members of the same class. Hence we should expect I.Q. differences due to environmental dissimilarities between the children of the former and the latter classes to average at least 15 or 20 points. And this is what has actually been found.

The results, then, show us that there is no scientific basis for the conclusion that the socially lower classes, or technically less advanced races, really have a genetically inferior intellectual equipment, since the differences between their averages are, so far as our knowledge goes, to be accounted for fully by the known effects of environment. At the same time, we are brought to realize that, in a society having such glaring inequalities of environment as ours, our tests are very unreliable for the determination of individual genetic differences in intelligence, except in some cases where these differences are extreme or where essential likeness of both home and outer environment can be proved.

If the above is true of intelligence, it is even more true of temperamental traits, moral qualities, etc., since these are more responsive to conditioning than are purely intellectual characteristics. Thus, our social system creates unemployment, slums and graft as surely as it creates great industries, splendid churches and universities, and in the former process it creates what it itself brands as criminality. It is well known that certain slum districts constitute veritable factories for the conversion into criminals of those who happen to be born in them, whether their parents were of the criminal class or not, and, as Jack Black for instance has shown, an analysis of the lives of various individual criminals reveals to what an extent potentially valuable citizens may be turned to a life of habitual crime through the pressure of our social system. Under these circumstances it is society, not the individual, which is the real criminal, and which stands to be judged.

Naturally, the apologists for the still existing order would have us naïvely accept appearances at their face value. Their justification of the existing order requires this acceptance. This is bound to lead to a false genetic valuation of individuals, of classes and of races, so long as this system lasts. The apologists defend their position with the *a priori* argument that, in the social struggle, the better rise to the top. They neglect to show that success in modern economic competition depends on many other factors, besides innate endowment, and that to-day we have increasingly operative, instead, the principle of "to him that hath shall be given." But if we assume that inborn differences do play some rôle, the question is, what rôle? Are the characteristics which now lead men to rise, economically, those which are the most desirable, from a social point of view? It could at least as well be maintained that the dominant classes tend to have the genetic equipment which would be least desirable in a well-ordered social system, since they have been selected chiefly on the basis of preda-

tory, rather than truly constructive, behavior. A study of the lives of many eminent financiers confirms this. The "respectable" captain of industry, military leader or politician, and the successful gangster are psychologically not so far apart. The high-minded, the scrupulous, the idealistic, the generous and those who are too intelligent to wish to confine their interests to their personal monetary success, these are apt to be left behind in the present-day battle.

This brings us to consideration of another topic: What should be the eugenic goal? And here we meet with a third source through which eugenics is irremediably corrupted by our economic system. So long as present conditions continue, the ideology of the people must in the main be a reflection of that of the now dominant class, and the standards, the criteria of merit of the latter, will be accepted. Naturally, those in power will idealize their own characteristics, particularly those which brought them to dominance. In so far as they concerned themselves about eugenics, would not most of them believe in the production of bigger and better business men, who could see us through bigger and better depressions? There would also be room for various accessory gentry, such as sportsmen of the type who symbolized the predatory life, slapstick and slush artists to keep us harmlessly amused, and some safe and sane scientists to invent better poison gas and to harmonize science with useful superstition. And perhaps the most benighted elements could be cajoled or coerced into developing themselves into more callous slaves, who could work longer hours on a cheaper grade of beans. Not that this fantasy would ever be realized, for, as I have shown, eugenics under our social system can not work. Nor are the distinctions between these types truly genetic ones. But that would unquestionably be the direction in which the ideology of the dominant class would logically try to lead eugenics, if it could do so. Only the impending revolution in our economic system will bring us into a position where we can properly judge, from a truly social point of view, what characters are most worthy of a man, and what will best serve to carry the species onward to greater power and happiness in a united struggle against nature, and for the mutual betterment of all its members.

This elevation of our moral standards and reconstruction of our concept of values will be intimately associated with a change to realism in our whole philosophical outlook. There will therewith be cast aside the whole antiquated lot of organized deceptions, of mandates, mummeries and prohibitions, ostensibly dictated from without, which it has so long been to the advantage of "upper" classes to maintain among "lower," and which the so-called "eugenics" of the present day shamelessly condones. In this system of mores, a prominent part has hitherto been played by the superstitions and taboos enveloping and contaminating the whole subject of sex and reproduction. The last noisome cobwebs of these dogmas will necessarily be swept away along with the other débris. Thus the way will be prepared for the entry, into these so important activities of man, of more real and comprehensive research, openly directed at the most vital problems, and of ever more thoroughly rational practises, fearlessly applied in accordance with the results of the research. In this way a fourth and very serious block to eugenics in our present society will have been done away with. The possibilities of the future eugenics under these conditions are unlimited and inspiring.

Galton may perhaps be pardoned for not having realized that the day was soon coming when there would be fundamental economic and social changes, which would utterly alter the complexion of eugenic problems. But in our

day the writing on the wall is manifest, and they are fools who blind themselves to it. Let us rather prepare with open eyes to face our new problems. There is no use in arguing about the effects, in a hundred years or more, of the continued differential reproduction of different classes, when the very basis for the existence of these classes as such is in process of disintegration, and in place of the economic conditions imposed by the class struggle, entirely new conditions will be substituted. Similarly, the present disputes of eugenists about the fates of races will soon appear vain and beside the point, when the economic and social reasons for the existence of the differential fertility of races, as well as for race prejudices, will have disappeared with the general abolition of exploitation. True eugenics can then first come into its own and our science need no longer stand as a mockery. For then men, working in the spirit of cooperation, will attain the social vision to desire great ends, and to judge of what is a worthy end. Then first, with opportunities extended as equally as possible to all, will men be able to recognize the best human material for what it is, and garner it from all the great neglected tundras of humanity. Then, too, and not before, will the economic basis of society be such as to allow a truly social control over differential fertility.

That imminently impending society, ordering its processes consciously for the common good, assures every one economic plenty, takes away a large part of the burden of the children from the shoulders of the individual couple, and especially from the woman, and so makes it possible for them to decide by considerations of the interests of the future generations, and of the race as a whole, rather than of themselves, how many and what children to have. In this decision they will not be hampered by ancient animistic fears and prejudices. Thus it is up to us, if we want eugenics that functions, to work for it in the only way now practicable, by first turning our hand to help throw over the incubus of the old, outworn society.

## Summary

It has been shown that eugenics under capitalism involves several serious contradictions:

(1) Under the capitalist system of economics, the fulfilling of the eminently social function of producing the next generation entails an excessively heavy individual burden which, added to the other economic stresses affecting most of the population, and especially the women, under this system, constitutes an often intolerable affliction. As a result, individual economic considerations rather than considerations of the genetic worth of the future generations must in the main govern human reproduction, in so far as the latter is voluntary at all, and eugenics must remain an idle dream.

(2) In order to justify the existence of the gross economic and social inequalities between classes, races and individuals, arising under our present economic system, it has been necessary for the apologists of this system to put forward the naïve doctrine that the economically dominant classes, races and individuals are genetically superior. Such scientific evidence as is available fails to support this contention, and shows that the differences in scores on so-called "intelligence tests," made by different races and classes, are, to the best of our knowledge, caused by the differences in environmental advantages which they received. On theoretical grounds, in fact, there is at least as much reason for supposing that the dominant classes represent a selection of socially inferior, as of socially superior genetic material. Thus capitalism leads to a false appraisal of the genetic worth of individuals, and of vast groups,

which results in entirely mistaken conceptions of eugenic needs.

(3) Our economic system, by exalting the acquisition of private profits, regardless of at what expense to others they were obtained, inculcates predatory rather than constructive ideals. In consequence, the ideal set of characteristics which most present-day eugenists and the population at large would set up as a eugenic goal, is far from the type which would be considered most desirable in a well-ordered society.

(4) It is advantageous for the dominant classes, under our present system, to foster a set of archaic superstitions and taboos, and these are directly antagonistic to rational, civilized practises regarding sex and reproduction.

Hence the impending radical changes in our economic order are prerequisite to a genuine, functioning eugenics.

# THE GROWTH AND REPAIR OF NERVES

By Dr. CARL CASKEY SPEIDEL

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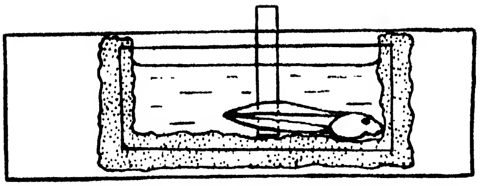
By a special technique I have found it possible for the first time to watch directly in the living organism two fundamental activities of nerve fibers. These are (1) the behavior of the actively moving tip of a single fiber as it grows toward the skin, and (2) the process of formation of the myelin sheath which later encases the fiber.

Small frog tadpoles are used and the observations are made on the developing nerves of sensation in the transparent tail fin. While the animal is kept lightly anesthetized, a region may be studied for a period of several hours. The tadpole is then replaced in pond water and the following day the same region and the same nerve fibers are again observed. In this manner the same individual fibers and sheath cells have been watched daily for as long as several months.

Experimentally, many actively growing nerve sprouts may be induced if the tip of the tail is sectioned and regeneration allowed for a few days. At the tip of each sprout is an enlargement, called a "growth cone." While at rest the growth cone is rounded and smooth in contour. In action, however, a number of extremely delicate processes are continually being extended and retracted, as if the immediate vicinity is being explored for a favorable route. The growth cone advances by a slow irregular flowing motion, spinning the nerve fiber behind it. It often displays a marked tendency to follow the fibrous processes of tissue cells which it meets.

A slight temporary obstruction in the path of the growth cone may cause a small thickening, or varicosity, to be left behind. A more formidable obstruction may lead to giant cones or to the formation of branches. Occasionally, when an insuperable obstacle is encountered, the growth cone is pinched off, and a new cone develops, which then starts its progress in a new direction.

Following the first, or pioneer, cone of growth come the second, third and later cones, each spinning a fiber of its own. As these usually adhere to the first fiber, a small nerve is thus formed. Ordinarily these grow out in the same direction, but a few cases have been seen showing that two growth cones may migrate along a nerve in exactly opposite directions at the same time, thus passing each other. Several varieties of nerve nets, or anastomoses, have also been observed in process of formation. Subjection of the entire animal to electrical stimulation causes no appreciable

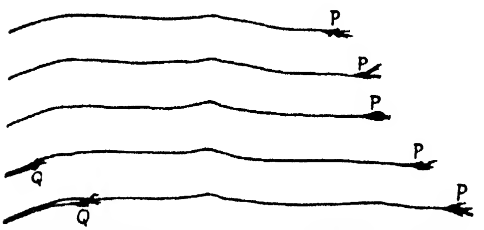


THIS DIAGRAM SHOWS THE TADPOLE IN THE OBSERVATION CHAMBER. THE ANIMAL IS KEPT LIGHTLY ANESTHETIZED. A REGION IN THE TRANSPARENT TAIL FIN IS SELECTED FOR MICROSCOPIC STUDY AND A MAP OF THE NERVES IS MADE. THE ANIMAL IS THEN REPLACED IN POND WATER AND THE FOLLOWING DAY THE SAME NERVES ARE FOUND AGAIN FOR STUDY, AND THE GROWTH CHANGES MARKED.

effect, either on the rate or direction of growth of active cones.

As nerve fibers become more mature, many acquire a sheath consisting of a fat-like substance called "myelin." The myelin sheath protects, nourishes and insulates nerve fibers. It is formed in segments, the first ones appearing near the nerve roots. I have watched the complete process of formation of more than 100 myelin segments. Each segment is formed through the cooperation of a "sheath cell" and a nerve fiber. Not all nerve fibers, however, are equally ripe for myelination. Those sprouts which emerge from a myelin sheath are especially ripe for myelin sheath encasement, as soon as a sheath cell arrives.

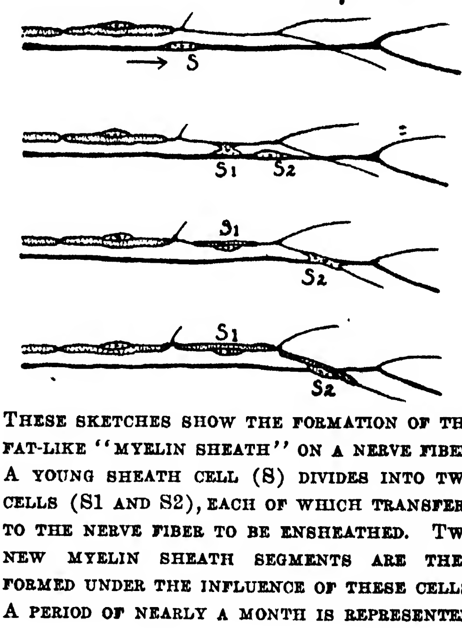
The myelin sheath is not very stable, and under conditions involving slight




THESE SKETCHES SHOW A PIONEER "GROWTH CONE" (P) ADVANCING TOWARD THE RIGHT SPINNING A NERVE FIBER BEHIND IT. THE SECOND GROWTH CONE (Q) FOLLOWS THE PATHWAY LAID DOWN BY THE FIRST. A PERIOD OF TWO HOURS IS REPRESENTED.

injury or irritation it degenerates. Many varieties of repair and readjustment of the myelin sheath have been watched. In all these a dominating rôle is played by the sheath cells. These cells exhibit exquisite sensitivity to near-by nerve injuries or abnormalities, and respond in an appropriate way to aid in the restoration of normal conditions. Under the proper stimuli they may travel in either direction along a fiber, or transfer from one nerve to another, or multiply.

Detailed histories of the stumps of sectioned nerves reveal that several varieties of nerve regeneration may be distinguished. The exact phenomena of repair depend partly upon the composition of the cut nerve. Typical case his-




THESE SKETCHES SHOW THE FORMATION OF THE FAT-LIKE "MYELIN SHEATH" ON A NERVE FIBER. A YOUNG SHEATH CELL (S) DIVIDES INTO TWO CELLS (S1 AND S2), EACH OF WHICH TRANSFERS TO THE NERVE FIBER TO BE ENSHEATHED. TWO NEW MYELIN SHEATH SEGMENTS ARE THEN FORMED UNDER THE INFLUENCE OF THESE CELLS. A PERIOD OF NEARLY A MONTH IS REPRESENTED.

tories have been obtained of the following: (1) section of small unmyelinated nerves (a) without anastomoses distal to the cut, (b) with anastomoses distal to the cut; (2) section of single isolated myelinated fibers; (3) section of small mixed nerves; (4) section of large nerves; (5) collateral regeneration.

The early changes associated with

nerve irritation have never been adequately observed and recorded in the literature. My observations indicate that profound disturbances immediately take place following injury. A myelin segment shows a pronounced fluid reaction with swelling, vacuole formation between myelin sheath and axis cylinder, and faintly visible currents within the axis cylinder. The myelin sheath exhibits a typical rippling and twisting activity. The axis cylinder assumes an irregular wavy course and its neurofibrillar structure becomes visible. The sheath cell nucleus becomes glassy, as though its contents were becoming liquefied, and it becomes less intimately applied to the myelin sheath. The vacuoles later disappear and the entire axone straightens, though it remains somewhat swollen for some time.

A segment appears to straighten by a "turgor reaction." If the irritation is not too great, the fiber may become normal again, the neurofibrillar structure becoming invisible. If, however, the fiber has been separated from its nerve cell or the irritation from another source is quite marked, typical degeneration follows with the myelin breaking up into ellipsoids and later into granules.

Recently I have succeeded in obtaining motion pictures of nerve fibers during the processes of growth and myelination, irritation and recovery, degeneration and repair. The pictures are taken at a rate such that, when projected on the screen, all movements are speeded 128 times (in some cases, only 32 times). Thus, the changes over a period of two hours may be exhibited by motion-picture film, which requires only one minute for its projection. Ciné-photomicrographs of this type beautifully reveal slow movements of the nerve fibers and the surrounding tissues that might otherwise escape notice.

Among the nerve activities which I have recorded by the motion-picture method are the following: the progress of the first, second and later growth cones of single nerve fibers; anastomosis formation; retraction; movements of fibroblasts and their effect on nerve growth cones; movements of sheath cells; mitoses of sheath cells; addition of new myelin segments at the end of a fiber; formation of a myelin segment at a node of Ranvier side-sprout; the actual, though slight, extension of the myelin sheath over a period of two hours; invasion of degenerating, regenerating and normal nerves by leucocytes; deformation of nerve fibers by tension of connective tissue cell processes; stimulation of nerve sprout formation by fibroblast mitosis; traumatic irritation of a proximal stump myelin segment and its recovery; the earliest changes associated with trophic (Wallerian) degeneration; irritation and recovery of a myelin segment following a near-by non-nervous wound.

# THE PRESERVATION OF OBJECTS OF ANTIQUITY

By Dr. HERDMAN F. CLELAND

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If the works of the ancients are as much the heritage of future generations as they are of the scholars of the twentieth century, failure on the part of present-day archeologists to conserve this heritage would seem, to put it mildly, unfair. If this assumption is correct a discussion of means by which objects of antiquity can be preserved would seem to be pertinent; if not, it is without point.

In a recent article[1] the writer called attention to the failure of archeologists to take adequate measures to prevent the destruction of their archeological discoveries. The purpose of this paper is to discuss the problems of preservation.

## Examples of Slow Disintegration in Nature

Under certain conditions objects are preserved by Nature for long periods without artificial aid. For example, when the covering of glacial drift was removed from the discovery vein[2] at Cobalt, Ontario, the workmen were astonished to find a broad band of untarnished silver which was so wide that they called it the "Silver Sidewalk." A similar discovery was made at Sudbury, Ontario,[3] where the surface of the ore shone like burnished copper when first uncovered. These surfaces were polished and later covered with drift by the last Great Ice Sheet which disappeared from Ontario possibly 20,000 or more years ago. During the Bronze Age in Sweden pictographs of historic events were chiseled on smooth, glaciated surfaces. Where overlain by a protective covering, they have been preserved to the present although they were made three or four thousand years ago. One such pictograph engraved on limestone was recently uncovered by Swedish archeologists but so rapid was the attack of the weather that it was found necessary to rebury it.

The remarkable mural paintings in the cave of Altamira[4] in Northwestern Spain are nearly as fresh as when painted thousands of years ago. The nearly perfect condition of the skin-like texture of the Hermes of Praxiteles at Olympia was due to the burial of the statue in wet mud where it lay for nearly two thousand years.

In the examples cited above water was present but was not in movement or, if so, the rate was so slow as to be negligible. As a consequence, there was no renewal of carbon-dioxide and oxygen, two gases which are active only when dissolved in water or in loose combination with water.

Wood may be preserved for centuries if it is immersed in water where it will be free from wood-destroying fungi and nearly free from bacteria. The only wooden objects made by Neolithic man on exhibition in museums are those which were buried in the mud at the bottom of lakes or in swamps. The poplar piles upon which the first Campanile in Venice was built in 900 A. D. were found to be strong enough, when reinforced, to support the weight

[1] "The Crime of Archeology," The Scientific Monthly, August, 1932.

[2] Letter from Professor A. P. Coleman.

[3] Letter from the late Dr. W. M. Miller.

[4] H. F. Cleland, "Weathering under Constant Conditions," *Science*, Vol. LVI, No. 1458, Dec. 8, 1922, pages 660–661.

of the tower which was rebuilt in 1905–11. It is evident from the above that water does not necessarily hasten decay, but is a passive agent in some cases and possibly a preservative in others.

It is a matter of common observation that where the air is dry, where there are slight changes in temperature and where light is excluded, objects disintegrate slowly. Finds in graves in Egypt, Peru, and other arid countries afford many examples. Elaborate ornaments, centuries old, made of feathers, as well as quantities of cloth, have been found in Peru. An interesting example of preservation under such conditions is to be seen in a piece of linen cloth decorated with two bands of tapestry weaving in wool, from Egypt, but now in the British Museum, which was made about the fourth century of our era. Other pieces of cloth from the same region date as far back as the sixteenth century B. C. Wooden objects from some Egyptian tombs seem nearly as fresh as when buried, and the colors are still bright. The reasons for this preservation, as already pointed out, are evidently (1) the fact that there was no moisture in which the carbon dioxide and oxygen gases could be dissolved (these gases are inert when dry), (2) the constant temperature and (3) the absence of light.

There are four other points which should be considered. (1) Great pressure may accomplish nothing more than to prevent the movement of water, and, except when columns are made of rocks which are under strain, may be disregarded. (2) When a rock is many times alternately wet and dried the effect is to cause it to crumble. This is because practically all types of rocks contain small amounts of soluble matter that can be leached out by water. When this soluble matter forms crystals within the rock, the growth of the crystals exerts a strong wedging action which often results in spalling the surface. (3) The repeated expansion of stone by daily changes in temperature loosens the grains of the rock and causes it to crumble. These last two agents of the weather are probably the most important in the Mediterranean Basin. (4) The effect of light on colors and on some substances is well known. For example, the mineral realgar (AsS) changes to orpiment ($As_2S$) when exposed to light for a few years, and the color of some stones, such as rose quartz, fades.

The preservation of the original substance of calcium phosphate shells of Cambrian Age for some 500,000,000 years and of the nacreous luster of calcium carbonate shells in Cretaceous formations for 100,000,000 years or more show that under certain conditions objects are practically imperishable.

### Suggestions

Little difficulty will be encountered in preserving for many centuries, possibly for thousands of years, objects which can be kept under cover. If museums are properly constructed and are equipped with apparatus which will keep the air at a uniform temperature and nearly free from moisture, and if corroding gases and bright sunlight are excluded, there seems little doubt but that objects contained in them will remain in approximately their original condition for many centuries.

This fact is well illustrated by the condition of objects of many materials in the ancient Japanese treasure house of Shoso-in[5] where they have been stored for nearly 1200 years. The story of this unique and remarkable building is of great interest in this discussion. It is briefly as follows: Upon the death of the emperor Shomu in 756 A. D., the empress gave as a memorial to her husband all of the imperial treasures and the personal belongings of her husband. These were stored in the Todajii monastery

[5] Asa Matsuoka, "Shoso-in-Ancient treasure House." Pub. by Japan Society, New York, 1930.

which, when enlarged to accommodate the memorial, was 108 by 48 feet and 39 feet high. The building is supported on pillars which raise it 9 feet above the ground. The walls are made of triangularly fashioned timbers, probably of cypress, held together by wooden pins. There are no windows and only three doors. Consequently, no light enters the building. Because of the absence of light the original colors of the objects are as perfectly preserved as if recently installed. The building is self-ventilating. In the dry season the timbers of the walls and the boards of the floor shrink and air enters; in the wet season the timbers swell and moist air is excluded.

The building is now opened to an invited group of visitors once a year, but in the past it had remained unopened for as long as one hundred years, and the shortest period previous to 1872 was thirty years. In 1892 the treasures were taken from the chests in which they had been kept for more than 1100 years and placed in glass cases.

In this paper we are concerned chiefly with the preservation of materials. Chests, tables, and desks of wood, screens covered with textile fabrics, paper, and feathers, incense, medicines, documents of white linen paper, ancient arms and armor, ivory objects, bronze mirrors and coins, "shark-skin," leather shoes, leather saddle trappings, and silk and cotton cloth are all in a remarkable state of preservation. Sword blades, halberds and spears shine as though they were placed there yesterday.

Such is the condition of the treasures of Shoso-in after nearly twelve centuries. They demonstrate that with intelligent care objects in buildings may have a long life.

The Japanese have also recently[6] called science to their aid in an attempt to preserve for at least 10,000 years the names of the victims of the Japanese earthquake of 1923. Names of the dead were written in China (carbon) ink on a fine grade of paper. This record was then inserted in bottles made of fused quartz. The air was exhausted from the bottles and the vacuum thus created filled with argon gas. The quartz bottles were wrapped in asbestos and sealed in a lead container which in turn was placed in a fireproof carborundum cylinder. Argon gas was probably used because of its inertness and because, being denser than nitrogen, it has a slower rate of diffusion. Although these records may be preserved for thousands of years they can not be seen.

It is evident that with proper care smaller objects can be saved from decomposition and at the same time be available for study at reasonable expense. But the vast ruins of temples and other works of antiquity present a much more difficult problem, and one which has not yet been solved.

From the examples cited it is clear that either water must be excluded from objects, or, if present, it must be sealed in so that it can not be renewed. The need, therefore, is for a durable, transparent, waterproofing substance. Such a substance has not yet been invented. Coating with paraffine has proved to be nearly useless, as the experience with the Egyptian obelisk in Central Park, New York City, clearly shows. It is for water-proofing substances that the research chemist should be urged to labor.[7]

There is one agent of the weather

[6] *Illustrated London News*, September 5, 1931.

[7] Dr. C. S. Piggot in a letter, received since this article was in the hands of the printer, states that he has experimented with tetramethyl-orthosilicate as a preservative for stone. The substance penetrates into the stone for a considerable distance, hydrolyzes there, producing ethyl alcohol which evaporates out, and deposits $SiO_2$ in the pores. Repeated treatments tend to fill the interstices with $SiO_2$ thus rendering the stone less porous and somewhat tougher at the surface. It is a liquid, safe to handle, and easy to apply. The stone must be dry.

which, in the present state of our knowledge, seems unconquerable: that is, disintegration resulting from changes in daily temperature. This agent will disrupt rocks which are exposed to the heat of the sun which expands them, and to the cool of the night which causes them to contract.

From the examples cited above, it seems clear that if objects of antiquity are to be kept from disintegration and at the same time are to be available for study they must either be kept under cover or protected by some artificial coating which will, in effect, accomplish the same result as enclosure in a building. For the larger ruins, such as those of Delphi, Olympia, and Delos, where the expense of a cover is prohibitive, the only alternative at present seems to be to rebury them after they have been carefully studied and illustrated. If and when transparent stone preservatives are discovered they can be reexcavated.

# ON FRANCIS GALTON'S CONTRIBUTION TO THE PSYCHOLOGY OF RELIGION

By Dr. ERNEST L. TALBERT
UNIVERSITY OF CINCINNATI

In his "History of Psychology," Professor Pillsbury writes a succinct and appreciative account of Francis Galton's work in general psychology upon imagery, association, sensory tests, instinct and the quantitative study of mental traits.[1] Professor Pillsbury does not mention Galton's constant reference to the mental processes of religious persons.

The second volume of Karl Pearson's "The Life, Letters, and Labours of Francis Galton" reveals a consuming interest in religion, its nature and its function. It is well known that Galton's version of religion had its setting in the theory of evolution, especially as understood by Darwin, and the intellectual climate of the Victorian era. For him the object of religious emotion is the process of life, operating by natural selection in its earlier stages, supplemented by artificial selection in its later ones. Of this cosmos, picturable in imagination as a unitary being, the individual may be looked upon as a cell, more or less unconscious of his full relation to the whole, just as the individual cells of the body serve organic functions without knowing why and how. It is possible for man to become increasingly conscious emotionally and intellectually of his ancestry and his posterity. It is his high privilege to aid the beneficent trends, warned by the results of disastrous and wasteful evolution during the pre-human stages. Mankind may in part determine its own future.[2] "Darwin had taught evolution as a scientific doctrine; Galton proposed that this new knowledge should be applied to racial and social problems, and that understanding of, sympathy with and aid in the progress of the general evolution of living forms should be accepted as religious duties."[3]

In order to realize the ends of evolution a change of values and of the method of educating youth is called for. Galton, like Huxley, is impatient of the

[1] Pillsbury, "History of Psychology," pp. 201–203, New York, Norton, 1929.

[2] Galton, "Inquiries into Human Faculty," pp. 194–198, New York, Dutton, 1928; "Hereditary Genius," p. 376, New York, Appleton, 1887.

[3] Pearson, "The Life, Letters and Labours of Francis Galton," Vol. II, p. 261, Cambridge University Press, 1924.

sectarian absolutism of his day. Mankind inherits the slavish and gregarious instincts of oxen and of other lower forms.[4] Conscience and intuitive principles date from past necessities and are no certain guide for the variables arising in the present. The hold of theological doctrine is imputed to habits and sentiments fixed in childhood. Intelligence and unfettered inquiry, recognized as essential in science, have not been applied to the phenomena of traditional religion.[5] Religious attitudes should be based upon science and its ministry to human welfare.

The time is ripe for methodical investigation of assertions which religious persons make about the nature of inspiration, existence of spirits and answer to prayer. The subjective aftermath of prayer is undoubted, its objective implications not so certain. The conclusive test is experimental. Galton insists upon applying statistical methods to the objective efficiency of prayer. Royalty are prayed for often, yet their longevity is less than that of other groups not designated in ecclesiastical ceremonial.[6]

Persons other than the religious are subject to idiosyncratic images and other unique mental happenings. In ages of miracle and faith these experiences are rated high in significance. In later centuries those to whom like experiences come attach no importance to them, since the community does not.[7] They conceal them, at least until solicited by questionnaires.

The visions and other mental states of religionists should be estimated in the light of known mechanisms of mind. Galton stresses the presence and activity of clusters of emotionalized associations not ordinarily brought into conscious focus. These usually subconscious contents can be drawn from the "antechamber of consciousness." They are attended to by the religious man, and their revival becomes automatic. The term "dividuality" is used by Galton to describe an experience in which subjective processes are taken to be objective by the dissociated self.

Divines are more sickly than members of other professional groups.[8] Excessive piety is sometimes related to sexual disorganization.[9] On the basis of limited biographical data Galton propounds a theory that "the chief peculiarity of the moral nature of the pious man is its conscious instability."[10]

Galton was essentially a frontiersman in science. His findings and conclusions have been subjected to scrutiny by subsequent students of religion. Some of his ideas have been rejected, others have entered into the body of anonymous material which every science contains. His views are cited not to defend their finality but to support the conviction that his pioneering in this field deserves recognition.

[4] "Inquiries into Human Faculty," pp. 55–56.

[5] *Ibid.*, pp. 149–152.

[6] "Statistical Inquiries into the Efficiency of Prayer," *Fortnightly*, August, 1872; other references cited by Pearson, *op. cit.*, pp. 115–117.

[7] "Inquiries into Human Faculty," pp. 127–128.

[8] "Hereditary Genius," p. 265.

[9] "Inquiries into Human Faculty," p. 46.

[10] "Hereditary Genius," pp. 281–282.

# THE DUDLEY OBSERVATORY CONTROVERSY

By WILLIAM K. PRENTICE

PRINCETON, N. J.

THE awakening among non-professional people in America, about the middle of the nineteenth century, of an interest in the advancement of knowledge, and of a desire that Americans have a place with the scientists of the older world in scientific discovery, is an interesting episode in the development of this country. Long before that time colleges had been founded here, chiefly for the purpose of training candidates for the professions. Some learned societies had been formed, such as The American Philosophical Society at Philadelphia in 1743 and The Academy of Arts and Sciences at Boston and Cambridge in 1780. During our revolution and afterwards, some of the leaders of the nation were fairly familiar with the philosophic thought and political theories of England and of France. But when, in 1842, an English astronomer was told that there had been organized in Cincinnati "an astronomical society of more than three hundred members from every rank, grade and profession in life, from the hard-working mechanic to the retired merchant, from the butcher in his stall to the professor in his gown," and that these had contributed funds to equip an observatory in their city with instruments of the best quality, the Englishman exclaimed: "This is a most curious, wonderful affair! A democratic astronomical society!" Something was happening then in the new world, which had not happened before, at least since the golden age of Athens.

At that time Americans were removed by only a few generations from the conditions of actual pioneers who hewed their homes from a wilderness and secured a livelihood by unremitting toil. The republic which they had founded was scarcely more than half a century old. Yet life, at least along the Atlantic coast, had become settled, and for many prosperous; many had now some leisure to devote to other things than the struggle to exist.

No branch of science appealed more strongly to these Americans than astronomy. It revealed to them something of the "wonders of science," and brought them directly into contact with the universe beyond the earth. Besides, this particular science had an application to practical matters which any one could appreciate, the determination of standards of time, the location of places by latitude and longitude, map-making and navigation. One of the pioneers of astronomy in this country was O. M. Mitchel, a graduate of West Point in the class of 1829, and from 1836 to 1845 professor of mathematics and engineering in Cincinnati College. In consequence of the interest aroused by popular lectures given by him in the winter of 1841–2 under the auspices of the Cincinnati Society for the Diffusion of Useful Knowledge, he organized the Cincinnati Astronomical Society, raised more than fourteen thousand dollars by private subscriptions in cash, due bills, work and materials, secured a gift of about four acres of land, built an observatory and installed in it a telescope made for it in Munich. When this telescope was mounted early in 1845 it was, with the single exception of the equatorial at Pultowa in Russia, the best refracting telescope in the world.

At Albany in 1851, at a meeting of ladies and gentlemen in a private house,

plans were discussed for establishing in the state capital a university of which an astronomical observatory should be a part. A letter from Professor Mitchel of Cincinnati on the value of astronomy was read at this meeting, and Professor Agassiz of Harvard made an address on the proposed University of Albany. It was decided to begin at once with the observatory. When subscriptions were invited $25,000 was raised in a short time, and several acres of land, suitable for an observatory, were given. Early in 1852 a corporation was formed, under the name of The Dudley Observatory and under the control of a board of fifteen trustees. The building was completed in the following year, and it was expected that Professor Mitchel would take immediate charge of securing the necessary equipment and staff; but since he was not able, at that time, to do this, the building remained for two or three years unoccupied.

It was no small ambition which inspired these citizens of Albany. They took no small interest in the intellectual development of the country. The discussion of plans for a National American University in their city continued, and a bill to support such an institution was presented to the state legislature in the winter of 1852–53. Evidently it seemed to many that the capital of New York State was as natural and proper a place for a National University as the Federal capital at Washington. These plans were not carried out. The Dudley Observatory, however, The Albany Law School and The Albany Medical School were founded. At the "inauguration" of the observatory, on August 28, 1856, Dr. Gould, its director, said: "The aspirations of our countrymen for some high educational seminary in the land, that shall receive American youth where the colleges leave them, and afford the same facilities for the highest culture in specialties, that the colleges offer for the general acquisition of information, refinement and taste; . . . and which shall supply to our own young men the combined sources of knowledge, which they have hitherto been compelled to seek on the other side of the ocean, have within a few years found expression in various places; but nowhere has the effort to bring the aspirations to fulfilment been so vigorous as in this city of Albany."

In midsummer, 1855, at the meeting in Providence of the American Association for the Advancement of Science, the affairs of the Dudley Observatory were discussed. Soon afterwards an arrangement was made by which the U. S. Coast Survey was to take for a time the direction and control of the observatory. The trustees, on September 3, 1855, appointed a scientific council, consisting of A. D. Bache, at that time superintendent of the U. S. Coast Survey and regent of the Smithsonian Institution; Joseph Henry, formerly a professor at Princeton and at that time first secretary and director of the Smithsonian; Benjamin Peirce, then professor of astronomy and mathematics at Harvard and in charge of the longitude department of the Coast Survey; and Dr. B. A. Gould, Jr., the founder and editor of the *Astronomical Journal*. Dr. Gould was sent abroad to procure instruments. In addition to her former contributions Mrs. Dudley gave $14,500 for a heliometer, and later $50,000 more towards an endowment. Two gentlemen, whose names were not given, assumed the responsibility for a meridian circle "to be provided without any limitation of expense." Another subscribed $1,000 for a sidereal clock, which was afterwards known by his name. All these contributors were private citizens of Albany.

So the beginnings of the Dudley Observatory were most promising and creditable to its promoters. In a little more than two years the resident director had

been forcibly expelled from the property by the trustees, the scientific council had been discharged and the operation of the observatory had practically stopped.

The Dudley Observatory controversy of 1858 had, at the time, a very wide publicity. The most influential member of the board of trustees, and from March 2, 1858, its president, was the president of one of the prominent banks of Albany and a man of very considerable influence. He and the secretary of the board, who from the beginning had been the most active promoter of the enterprise, took great pride in the observatory, and felt that to them in chief belonged the credit of its establishment. They wished the people of Albany to visit it, to be impressed by it, to wonder at it, and its instruments, and the mysterious work which was being carried on there. They wished, of course, to be regarded as patrons of science. They did not know much—perhaps they did not know anything—about astronomy or the necessary requirements of a scientific observatory. Yet they felt themselves competent to decide, contrary to the judgment of the director and the scientific council, on matters relating, for example, to the construction of the buildings and the mounting of the instruments. Apparently they believed that a scientific observatory could and should be managed as a bank was managed. The secretary of the board visited the observatory frequently, and gave orders personally on the authority of the trustees. The director, Dr. Gould, in his reply to the attacks of the trustees (p. 5) says: "I had for a long time had cause for complaint against one Trustee, whose constant interference with my plans, and whose foolish and lavish expenditure of money had occasioned me much annoyance and anxiety; and had led to earnest, though friendly appeals on my part, in behalf of the interests of the Observatory." The director and the scientific council refused to accept the direction of the trustees in matters which concerned the construction and operation of the observatory and the appointment of its personnel. They asserted that they had accepted the responsibility for the conduct of the observatory on the understanding that the final authority in such matters had been delegated to them by the trustees, and that on this understanding most of the money for the observatory itself, its instruments and its endowment had been contributed. This was all true. On the other hand, the trustees, in a resolution of January 9, 1858, asserted "that the Board of Trustees of the Dudley Observatory, as legal guardians of the Institution entrusted to their care, must claim an undivided and entire control over its property, the appointment of its officers and its general policy." According to the articles of incorporation, this was also true, unless the authority for the management of the observatory had been properly delegated to the scientific council. Thus there arose a clash of authority, and a determination on the part of some of the trustees to get rid of Dr. Gould.

The first definite expression of antagonism arose late in the year 1857 over the efforts made to secure the appointment of Dr. C. H. F. Peters to a position on the staff of the observatory. Dr. Peters was a native of Schleswig, a mathematician of considerable ability, who had found employment in the geodetic survey of the Kingdom of Naples, and later in Sicily and Constantinople, but no permanent situation. He came to America and was received by Dr. Gould, whose acquaintance he had made in Europe, into his house as a guest. Through Dr. Gould's efforts he secured a subordinate position as a computer in the U. S. Coast Survey. At his own request, he was sent to Albany to continue

his work for the Coast Survey there, to assist Dr. Gould privately, receiving for this service compensation from Dr. Gould personally, and to use, voluntarily, the "comet finder" of the observatory. Because of his failure to complete his work for the Coast Survey, however, in the summer of 1857 he was ordered to Cambridge to be under the immediate supervision of Professor Peirce, who had general charge of these computations. He then promptly resigned his position in the Coast Survey. Meanwhile he had won the support of some influential trustees, who evidently believed he would be more amenable than Dr. Gould. These trustees urged Dr. Gould to appoint Dr. Peters as his assistant at the observatory, but Dr. Gould, supported by the rest of the scientific council, refused. This led to a series of anonymous attacks upon Dr. Gould in the newspapers. A petition was circulated among prominent citizens of Albany and signed by a good many, urging the trustees to appoint Dr. Peters to the staff of the observatory. It was later proved, by the published testimony of one of the signers, that some, perhaps most of these signatures had been obtained by a misrepresentation of the facts. Acting upon this petition a majority of the trustees passed a resolution on January 9, 1858, appointing Dr. Peters as observer at the Dudley Observatory, in spite of the earnest opposition of several members of the board. The majority trustees, in their "Statement" issued later on, spoke of him as "a practical astronomer, a devoted lover of his science, and a faithful and diligent Observer." One of their number said: "To me he bears the genuine marks of a truthful, studious, laborious and eminent Scientist." Another called him "a ripe scholar, an accomplished astronomer." Dr. Gould and the scientific council had found Dr. Peters untrustworthy. The majority trustees seem to have regarded their action of January 9 as a dismissal of Dr. Gould and an appointment of Dr. Peters in his place. However, ten days later, the trustees reversed their decision, confirmed the "informal" election of the scientific council and resolved "that the Observatory, under the supervision of the Scientific Council, shall be immediately placed in operation, and in charge of Dr. B. A. Gould, Jr., and his assistants, in the employ and pay of the U. S. Coast Survey." Dr. Peters was thus eliminated, and soon afterwards secured a position as astronomer at Hamilton College. But this was by no means the end of the controversy. On the second of March, 1858, the board of trustees, consisting normally of fifteen, elected a new president, and appointed an executive committee of nine with full power, subject of course to the approval of the board. But, as these nine constituted a safe majority of the board, their action as an executive committee was practically final. Thus the minority members of the board were practically eliminated. On May 22 the majority trustees passed resolutions condemning those in charge of the observatory for lack of courtesy to the trustees, and demanding, among other things, free access for the trustees and their friends to the observatory at all times. On June 4 the trustees passed another resolution, asserting "want of harmony" between the administration of the observatory and the trustees. This resolution was communicated to the scientific council, which then asked for definite information from the board; but information was refused. On June 25, 1858, the president read to the board a "Manifesto," which consisted of a bitter and vicious attack on Dr. Gould, and this manifesto was adopted by the board, and published as a "speech" in the newspapers and also as a pamphlet. The board also passed at this time a resolution that their vote of

June 4 involved the immediate withdrawal of Dr. Gould as director, and another resolution that the board would no longer recognize Dr. Gould as a member of the scientific council. The other members of the council arrived in Albany on June 27 and requested a meeting with the board of trustees. This request was declined. The council then asked for evidence supporting the "Manifesto." This was also refused by the board, on the ground that the decision of the board was final. The council then investigated all the charges against Dr. Gould, issued to the trustees a protest against the proceedings of the board, and resolved to take personal charge of the observatory for a time, each of the three members of the council, excepting Dr. Gould, taking over the management personally for a month in turn. The result of this was that the board of trustees on July 3 passed a resolution dissolving all connection with the scientific council. Consequently, on July 10, the scientific council published their "Defence of Dr. Gould," of which three editions were issued, completely exonerating the director. This "Defence" aroused great indignation against the trustees. A large meeting of citizens was held which, after some discussion, voted unanimously in condemnation of the trustees, and appointed a committee of twelve to draft resolutions expressing the opinion of the meeting. The trustees replied by publishing a pamphlet of 173 pages, entitled: "The Dudley Observatory and the Scientific Council: Statement of the Trustees." Twenty-five thousand copies of this pamphlet were issued and sent throughout the country. It was a restatement and elaboration of the "Manifesto" issued in the preceding June. It was composed with considerable skill, and must have appeared most plausible to those who knew nothing of the actual facts. It assailed in detail the entire management of the observatory during Dr. Gould's administration, his ability and standing as an astronomer, his character and his integrity. But it was completely refuted by Dr. Gould's "Reply to the Statement of the Trustees," which was published in January, 1859, shortly after Dr. Gould had been forcibly ejected from the observatory. In 366 pages the director disproved every accusation of the majority trustees, repelled every insinuation and showed that most of what was produced in the "Statement" as evidence consisted of misstatements, incomplete, inaccurate and misleading quotations and actual falsifications.

Altogether, the published papers and documents relating to this controversy amount to at least 706 printed pages. The most significant are parts of the "Address to the Citizens of Albany," drafted by the committee of twelve appointed for this purpose at the public meeting held on July 13, 1858, to which allusion has been made. In this "Address" it is stated that the resolutions passed by the trustees on May 22 "were of a most extraordinary character; they proposed, in effect, to open the grounds of the Observatory to the public, as a park, or promenade; to convert the Observatory building into a public museum of curiosities; to place duplicate keys at the command of any of the trustees, so as to give them access, 'at any and all hours,' 'with or without friends,' 'to the Observatory and all its rooms.'" With regard to the "Manifesto" of June 25th, this committee asserted that "there does not exist, and there never has existed, the slightest foundation in truth . . . for any of the complaints, charges or accusations against Dr. Gould, contained in this paper. . . . Taking them together or taking them one by one . . . we pronounce them, one and all, merely, utterly and nakedly scandalous, without

a shadow of truth, reason or justice, to stand upon.'' Finally, in their closing paragraph, the committee says: ''It is possible that the Dudley Observatory may be saved, if the Board of Trustees would close with the proposition understood to be made, or about to be made, to them by the donors, to submit the whole subject of its difficulties to the arbitrament of several very eminent and unexceptionable gentlemen, as named in that proposition. Otherwise, we know of nothing now that can restore it to public favor, and to any possible usefulness, but the prompt and voluntary withdrawal of such of the Trustees as shall be found unwilling, after the developments and exposures which have been made, to cooperate with Professor Henry, Professor Bache, Professor Peirce and Dr. Gould, in a manner to enable them to prosecute and perform their proper duties to the Observatory, the donors and the cause of the science. This, or a thorough revision and alteration of its very exceptionable Charter by the Legislature, seems to us to afford the only remaining grounds of hope for the Observatory.''

Thus the Dudley Observatory was shipwrecked on that rock, which has been and still is an obstacle to the success and progress of institutions of learning in this country, namely, the exercise by a board of trustees of the authority, generally conferred upon them by the charter, to control directly the administration of the institution, and to appoint or discharge its personnel. It should not confuse the issue involved that this particular board of trustees, when their actions were challenged and criticized, resorted to personal attacks upon the director which were not supported by the facts. The Dudley Observatory controversy shows in one very extreme instance that trustees chosen to administer the finances of an institution are not ordinarily competent to decide the scientific questions which necessarily arise in its operation. The gist of the matter is correctly stated in the concluding paragraph of the ''Address'' of the committee of twelve quoted above. If the articles of incorporation of such institutions commonly give the ultimate authority in scientific matters to such trustees, these articles of incorporation should be changed. The awakening of interest in scholarship and science among the people who have no great training or experience in scholarship is wholly admirable and has been and is productive of great benefit to this country as a whole. But when this interest leads to the control of institutions of learning by persons who have not far more than an ordinary knowledge of scholarship, then this public interest is also a source of harm.

# SCIENCE SERVICE RADIO TALKS

## PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

# HOUSEHOLD HEALTH HAZARDS

By Dr. YANDELL HENDERSON

PROFESSOR OF APPLIED PHYSIOLOGY, YALE UNIVERSITY

I AM going to talk over with you some of the dangers that we are all exposed to nowadays. We all realize the hazards to life and health that the automobile has introduced, for many people are killed even in trying to cross the street. But the dangers that we are going to consider now are not so well known. They are quite largely hazards to health and dangers to life that occur in our homes.

Nearly all these dangers have developed rather recently. They are nearly all due to advances in science. You know that the advances in medical science have greatly decreased the deaths and illness from infectious diseases. The applications of medical science have made life much healthier and the average life much longer. A generation ago diseases like typhoid fever and diphtheria caused a heavy death rate, while now in a town or city with a good health department a year may go by with few or no deaths from these diseases. To a large extent this advance has been made by the health departments of our cities, our states and the national government. It is the fashion just now to criticize the government for costing so much and for requiring high taxes to support it. But the truth is that the service that the national, state and local governments render us simply in protecting our health is worth every cent we ever pay in taxes. It would be a disaster, if the effort to decrease the expenses of our various governments resulted in crippling the public health services.

We know that the police protect our property and our lives from criminals; that the fire departments protect our homes from fire; and that the U. S. Army and Navy protect us from foreign enemies. But we seldom think of the protection that the government gives us in regard to the food that we eat and that it should give us in regard to certain hazards to which our homes are now exposed. The most important protection of this sort is that afforded by the federal pure food law, and similar laws in the states together with the arrangements that the government maintains to see that the pure food laws are obeyed. The Agricultural Experiment Stations in many states are every day analyzing samples of foods that are being sold on the open market and these results are published in the reports of these stations. Impure foods are confiscated and destroyed. You can get one of these reports by writing to your state government.

Before the pure food law was passed any food producer could sell nearly anything that he could persuade the public to buy, no matter how much his product was misrepresented. I remember some strawberry jam that was highly advertised as a superior product, but it was found to consist of apple butter sweetened with corn syrup, flavored with a synthetic chemical flavoring, colored with a coal-tar dye, with artificial

wooden seeds scattered through the jar. The one thing that that jam did not contain was strawberries. It was like the wooden nutmegs that were once said to have been manufactured in Connecticut, where I live. I doubt the story about wooden nutmegs, but until the pure food law was enacted there were sausages made that had almost no sausage meat in them. And then there was the so-called embalmed beef that was alleged to have been supplied by some of the big packing houses to feed the soldiers in the Spanish War. I don't know whether Theodore Roosevelt, when he led the Rough Riders in Cuba back in 1898, ever ate any of that embalmed beef, for our soldiers in that war had very little to eat of any sort. But when he became President one of the measures he got Congress to pass was the pure food law. There was, of course, great opposition from some food producers on the ground of bureaucracy and interference with freedom of trade. But the law was passed and it has really been almost as valuable to producers and merchants as it has to consumers. It has not only prevented many cases of food poisoning and swindling by sale of inferior products; but it has also greatly increased the sale of all sorts of canned goods and foods in packages. So long as there was doubt of the purity and healthfulness of such foods people hesitated to buy them. Now they are sold in immense quantities, for every package of breakfast food, every can of vegetables and every bottle of pickle on the market is now subject to the supervision of the federal and state governments. All food products are required to be free from adulteration, and the label on the can or package must tell the truth about the contents.

Another big step to protect the American home was taken three or four years ago when Congress passed and President Coolidge signed a law called The Corrosive Poisons Act. This act requires a warning label on various chemicals and cleaning fluids that are used in nearly every home. One of these substances is soda lye that is used to clean the kitchen sink. Every now and then a little child got hold of the can and swallowed some of its contents. The result was fearful injury, lasting sometimes throughout life, even if the child was not killed immediately. All such substances must now bear a warning label, and many accidents are thus prevented.

But this is not yet enough. There are still many substances that are sold and that are very useful but which carry dangers into our homes. And against these substances, some of which are very poisonous, there are as yet no protective measures and no requirement for a warning on the label. A couple of years ago many cases of illness, and perhaps some deaths occurred in hotels, and some may have occurred also in private homes, where the forks and spoons were cleaned with a silver polish containing the deadly poison potassium cyanide. A few grains of this polish between the prongs of a fork were enough to cause serious illness. There was no warning on the label of that silver polish. It has been withdrawn from sale. But it was an excellent polish, and there is nothing now to prevent another manufacturer from putting out a similar polish containing potassium cyanide under a fancy name.

There is now on the market a powder for cockroaches. It contains sodium fluoride and has killed several people who took it by mistake. It is sold in a package that looks like that of salts. It has no warning on the label.

The largest group of poisonous substances that now go into our homes without any warning of their dangers are various volatile liquids and new chemical substances that are each year

invented by chemists, and put on the market and sold to the public, before any test has been made as to whether they are poisonous or not. For such substances there is as yet no requirement that the label shall give warning of danger. One of these substances that is very useful for cleaning purposes is carbon tetrachloride. Now let me say at once that carbon tetrachloride has certainly saved more lives and health than it has destroyed or injured. It is very much safer to remove grease spots with this liquid than it is with gasoline or naphtha, for carbon tetrachloride does not catch fire. It will not burn; but many a woman has been badly or even fatally burned by gasoline. On the other hand, carbon tetrachloride has a vapor that is distinctly poisonous. The substance should be used only in well-aired places so that the user does not inhale the fumes. In Switzerland carbon tetrachloride has been used as the solvent for a floor wax in a school. It caused serious illness. There is now no law or regulation in America to prevent carbon tetrachloride and similar new substances being used in floor polish. It can cause serious illness in children playing on a floor polished with such substances. There is no requirement now for a warning in the label on the can. It is not sold to the general public as carbon tetrachloride but under a fancy name. The next time you buy a bottle or can of cleaning fluid ask what it really is. In fact, when you buy any chemical for use in your home always find out what the constituents really are.

I do not want to give you the impression that American manufacturers wish to poison those who buy their products. They do not. They are humane men, and deaths or illness caused by their products react against selling their goods. The harm comes from the fact that when a new substance is invented by chemists and is found to be useful for some purpose, it is manufactured and sold without any investigation of whether its use involves hazards to health and life. Chemists had been looking for a substance that would prevent automobile engines from knocking; that is, from premature explosions in the cylinders and loss of power. At last an effective substance was found to be tetraethyl lead; and the manufacturers were about to distribute it all over the country to be added to gasoline at filling stations. Fortunately, scientific men who knew that tetraethyl lead is a powerful poison were able to warn the manufacturers in time. As a result the substance, instead of being distributed in concentrated form, is now mixed with the gasoline at petroleum refineries and distributed as "ethyl gas," which is relatively safe. Warnings are also put on the pumps at filling stations. There have been few or no cases of poisoning since these precautions were put into effect; but without these precautions there would almost certainly have been hundreds of cases of poisoning.

Another substance, methyl chloride, has, however, caused a number of deaths. This liquid or gas is used in some makes of automatic refrigerators. These refrigerators are certainly a great convenience as compared with the old-fashioned ice refrigerators. They are also quite safe if they are made in single units. Methyl chloride in a single unit refrigerator is perhaps safer even than most of the other gases that are used. But, unfortunately and unwisely, multiple systems of refrigerators were allowed to be installed in big apartment houses in some cities. Such an installation involves a big storage tank or cylinder of the refrigerant in the basement connected to many refrigerators in the various apartments. If any one of the refrigerators in any one

of the apartments develops a leak the whole of this large amount of gas from the cylinder and from all the other refrigerators in the building escapes into that one apartment. This occurred in some apartment houses in Chicago and caused a number of deaths a year or two ago. Large multiple refrigerator systems are dangerous. Single units are safe.

I could easily tell of other examples of the household hazards that modern scientific conveniences have introduced into our homes. The electric light fixtures in a bathroom should always be so arranged that no one can make contact with a live wire with one hand when his other hand is in a wash basin or his feet in a bath tub. Cases of death by electrocution by the house current have occurred under such conditions.

There are also the dangers from the city gas that we cook with nowadays. Old and defective rubber tubes leading to gas stoves are liable to break and to allow the gas to escape. Deaths from this cause are common. Water heaters, if badly arranged, may also produce carbon monoxide. Every gas heater should be connected with a chimney to prevent this danger. Another common danger nowadays is that from carbon monoxide in automobile exhaust gas. Never start the engine of your car, no matter how cold the weather, until you have opened the garage doors.

# TRANSPLANTING OUR MINDS

By Dr. A. T. POFFENBERGER
PROFESSOR OF PSYCHOLOGY, COLUMBIA UNIVERSITY

I FEEL impelled to apologize for the title of my talk to you this afternoon, after having recently seen a motion picture in which personalities were transplanted. By means of electrified belts worn by each of two persons, the personality of the one could be transferred to the other with consequences that were most amusing. It is not such transplantation of the mind that I am thinking of, nor is it the interchange of the brains of two individuals about which I have recently read in an exciting bit of fiction. It is the far less spectacular process of imagining yourself in the other fellow's place.

In the days when successful men of business and industry were wont to explain their success in the popular magazines—how long ago it seems since there were such successful business men!—there was one trait that always received a fair share of the credit. That was the knack of getting along with other people. It was attributed to the ability to project oneself into the other person's circumstances, to step into his shoes, to see problems through his eyes. Whatever expressions might be used to describe this magic operation, they all boiled down to this knack of imagining oneself in the other person's circumstances and thinking what one would do in his case. Of all the explanations suggested for the present economic disaster, I have never heard any one attribute it to the practise of transplanting minds, as I have defined it. On the contrary, every interpretation that I have studied would acknowledge the failure to transplant minds, in the sense in which I have used this expression, as an essential element of the problem.

The rapid changes in social and economic conditions which are occurring throughout the world have not affected all people in like manner or to a like degree. As a consequence, there never

was such a need as at present for great public leaders who could see problems through other people's eyes; and there never was such a need for every one to exercise the same bit of magic. Differences in outlook exist between races, between nations, between economic strata, and between social strata, between those who are employed and those who are not, between the employer and the employee, between parents and children, between the farmer and the city worker, between the white collar worker and the laborer, between the radical and conservative, between union and non-union men, between the racketeer and the law-abiding citizen. If each of these groups or individuals could project himself in imagination into the circumstances of the other, how soon the problems would be dissolved.

If the employee secure in his job could in imagination exchange his state of mind for that of the person who, through no fault of his own, is out of a job, he would get real satisfaction in relinquishing a percentage of his salary for the unemployed. If the family of the former wage-earner, now out of a job, could see the situation as he sees it, there would be more forebearance and sympathy with his depression and his irritability.

There is nothing new in what I have said, and I am sure there will be no objection to it. In fact, it is merely a kind of round-about definition of sympathy, which means feeling oneself into the situation or circumstances of another.

The problem consists in discovering how this transplanting process can be facilitated, and it is that which I wish to discuss with you. The one great underlying condition of sympathy is knowledge or information. We can not conceivably put ourselves in the place of another unless we know about him. This is true whether we are dealing with the relationship of one nation to another or one individual to another. Those persons who are most deeply concerned with international problems recognize the essential need for the mutual exchange of information. Many agencies have been set up for such exchange, although on a relatively small scale. There are exchange professorships, exchange scholarships, traveling fellowships, international student residence halls and international conferences of all sorts. The great peace conferences, economic conferences and armament conferences will accomplish much in the minds of those who are directly affected by them.

What is needed is a similar spread of information among the great masses of the population. Even here there is occasion for encouragement with world newspaper services, motion pictures and international broadcasts. The world is rapidly becoming smaller and more closely interrelated. Our public school system could and should do a great deal more than it does to further knowledge and understanding of places and peoples. It has control of the minds of the young, just at the time when sympathies as well as prejudices are most readily formed.

Every intelligent person should consider it his duty in times like these to get what authentic information he can about other nations and other peoples, by travel, by reading or whatever other means may be available. It is worth remembering in this connection that information about individuals is always more effective in arousing sympathy than information about whole populations or whole nations or whole races made up of these individuals. The detailed story of one starving Chinese is more effective in eliciting a charitable response than the mere report of a million Chinese dying from famine. The remarkable response each year to the

*New York Times* appeal for "The Hundred Neediest Cases" is due in large measure to the detailed account of each case, thus furnishing the means by which the reader may put himself in the place of the other. Without such a recital of conditions, the response would be cool.

The maudlin sympathy extended to the hardest criminal, so frequently deplored, is the direct result of the vivid descriptions of him presented by the press. People do not thus deliberately intend to defeat or weaken the ends of justice, but their sympathy is the immediate effect of knowledge.

Such instances as this show the involuntary character of sympathy. They should be encouraging instead of depressing, in that they demonstrate the possibility of engendering broad sympathies, of putting ourselves in the places of other persons, groups, nations and races, if their cases can be as vividly portrayed as that of the condemned criminal.

Still, I must hasten to add that the feat of mind transplantation is not so simple as I have made it to appear thus far. Something more is needed, and that something is a knowledge of how people's minds work. Now, I do not mean to suggest that every one must become a psychologist in order to acquire the essential sympathy and understanding that our present-day problems require. No profound knowledge of how the mind works is necessary, at any rate, for a few simple facts will suffice. Would it not enable us to see more clearly through the eyes of the social revolutionist whose conclusions appear so illogical, if we could discover that our own ideas are equally illogical? Or to look with sympathy upon him whose greed for money or ambition for power leads him into the toils of the law, if we were to discover that the same impulses are driving us, too, but perchance with a more fortunate outcome?

"Know thyself" is a bit of advice almost as old as written communication, but it is as important to-day as when it was first expressed. To know ourselves requires that we shall be able to examine and report our findings without prejudice or favor. That this is not easy to do was doubtless in the mind of Robert Burns when he wrote:

> Oh, wad some power the giftie gie us
> To see oursel's as ithers see us;
> It wad frae monie a blunder free us
> And foolish notion.

When we do succeed in seeing ourselves in this objective fashion, one of the first things we find is that our actions are seldom the result of the application of cold logic or reason. We seldom, if ever, think things out and then come to a conclusion. Our lives are guided far more by our emotions than by our reason. The demonstration of the importance of the emotions in everyday life is the great contribution of the Freudians to modern psychology. They have popularized the term rationalization to describe the way our minds work. It is a kind of thinking backwards, a means of giving rational support for something that we have already decided to do, or for something that we wish to believe. William James, forty years ago, pointed out this peculiarity of the human mind, and recent laboratory studies have given support to it. For example, in one experimental study of beliefs it was found that the relationship is much closer between our beliefs and the things we wish to believe than it is between those same beliefs and the quality and amount of evidence bearing upon those beliefs.

Modern advertising capitalizes this peculiar human trait. It arouses our desire for the object which it offers by appealing directly to some one or more of our many appetites, and having done

this it helps us to support our action by a kind of logic. Rigorous thinking would require that we accumulate evidence, get all the facts, and then after an examination of these facts reach a decision. It will be clear to all of us that the positions we take on many or most of the vital questions of to-day can not be the result of thinking, but must certainly be the result of this short-cut rationalizing process. It would not be possible in our busy lives to do otherwise. It seems, moreover, to be in our natures to avoid thinking, if any less arduous substitute can be found. Even a rigorous scientific training does not entirely counteract this tendency.

Let me assure my hearers that it is not my purpose to reconstruct our mental machinery by a few words of advice. We can not so readily mend our ways. It is my purpose rather to beg that we take an objective attitude toward ourselves, and look with humility upon the beliefs and attitudes which we cherish with such vehemence. Having achieved this end, we can react with sympathy and understanding toward the minds of others whose differing racial background, national history, social status or economic security give them an equally different outlook on life. To inform ourselves thus concerning other people and to see them with the understanding that can only come from a real knowledge of oneself, would in truth make this world a more fit place in which to live.

# "SQUARING THE CIRCLE"

By Dr. EDWARD KASNER
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I AM going to talk about the most famous problem in the entire history of mathematics, known as "the squaring of the circle," or more technically, "the quadrature of the circle." I shall discuss also two other problems which became famous among the Greek geometers, namely, "the duplication or doubling of a cube" and "the trisection of an angle."

These three problems have occupied the attention of great and small mathematicians for the past two thousand years, and interest in them will never cease. The main reason for this interest is that all three problems, in spite of their apparent simplicity, are not merely difficult, but are actually impossible. What is meant by this impossibility? That is the main point which is usually misunderstood, and I shall proceed to clear up the misapprehensions connected with the subject.

Mussolini, in a recent interview with Emil Ludwig, made this statement, "There is no such thing as the impossible." That may be true in the domain of statesmanship or of physical inventions, but it is certainly not true in mathematics.

The squaring of a circle, in the way in which the problem is to be understood, is absolutely impossible. It has never been done and it never will be done. What is the problem? It is to construct a square equal in area to a given circle by means of an exact theoretical plan, using only two instruments, the ruler and the compass. By a ruler is meant a straight edge, that is, an instrument for drawing a straight line, not for measuring inches or lengths. By a compass we can draw a circle with any center and any radius. These instruments are to be used a finite number of times (so that we can not use limits or

converging processes with an infinite number of steps), and the construction, by purely logical reasoning, depending on Euclid's axioms and theorems, is to be absolutely exact. Of course if we give up any of the requirements stated above the problem becomes possible. Very approximate solutions with ruler and compass are known in great variety; and exact solutions with higher instruments, like rolling wheels and integraphs, are easily obtained. The impossibility arises because we demand an *exact solution* by means of *ruler and compass,* employed a *finite number of times.*

The Greeks and later mathematicians tried to find an exact construction with ruler and compass and always failed. Does that show the impossibility? Of course not. It might merely indicate the difficulty of the problem.

For centuries the problem of constructing a regular polygon of 17 sides was considered difficult and even impossible. Yet the nineteen-year-old mathematician, Gauss, in 1796, succeeded in finding an elementary construction. In the case of squaring the circle, however, all doubts were finally removed in the year 1882, when a German mathematician, Lindemann, published a proof that the problem is impossible. The proof is long and complicated, since it requires the establishment of the fact that the number $\pi$, the ratio between the circumference and diameter, is transcendental. Up to the year 1882 circle squarers had the moral right to try to solve the problem, but after that date their efforts are to be regarded as waste of time and deserve no consideration from serious scientists.

The fact that the two other famous problems of Greek geometry are also impossible was settled about one hundred years ago. The duplication of the cube involves the cube root of two, and this can not be found by ruler and compass. There is a story among the Greeks that this problem originated in a visit to the Delphic Oracle. There was an epidemic at that time and the Oracle said that the epidemic would cease only if a certain cubical altar to Apollo was doubled. The masons and architects made the mistake of doubling the side of the cube, but that made the volume eight times as great. The Oracle was not satisfied so the Greek mathematicians began to see that the right answer involved, not doubling the side, but rather multiplying the side by the cube root of 2. This they could not do geometrically with ruler and compass. Finally they succeeded by using other instruments and higher curves, and the epidemic ceased.

A few words now about the final problem, trisecting an angle. This has received a good deal of attention in the newspapers during the past few years on account of the fact that several teachers of mathematics in high schools and colleges in this country have claimed that they have solved the problem completely.

It turns out, however, that all these published solutions are absolutely incorrect. The error committed is usually of one of four kinds: sometimes the solution is merely approximate instead of exact; sometimes instruments other than the ruler and the compass are used, consciously or unconsciously; sometimes there is a logical fallacy in the pretended proof; sometimes only special arbitrary or general angles are considered. New trisectors will always appear, but newspapers should not give them any further attention.

As long ago as 1775 the Paris Academy was so overwhelmed with pretended solutions from circle squarers and angle trisectors that a resolution was passed that no more would be received. This was, perhaps, a little unwise, because at that time impossibility was suspected rather than proved.

Of course Mussolini, whom I quoted before, is correct in suggesting that we must not say too rashly that any problem which is considered very difficult in a certain stage of culture is actually impossible. Several good scientists of two generations ago are on record as saying that it would forever be impossible to invent a practical heavier-than-air flying machine. The French philosopher, Auguste Comte, said that it would always be impossible for the human mind to discover the chemical constitution of the stars. You all know how, not long after that statement was made, the spectroscope was applied to the light of the stars, and now we know perhaps more about the chemical constitution of the stars, including those in the distant nebulae, than we know about the constitution of the earth with its largely unknown interior. Helium was discovered in the sun before it was found in the earth.

Is the problem of "shooting a rocket to the moon" impossible? No, it is merely very difficult. It would be much more difficult to reach the planets or the sun or a distant star, but we have no right to apply the adjective "impossible." Such problems seem extremely hard, and perhaps will not be solved for millions of years, but we have no logical ground at the present time to say that they are absolutely impossible. However, in the case of "squaring the circle" or "trisecting the angle" (with the restriction to ruler and compass of course) we have the right to say now that they are forever impossible, because we have found logical proofs, involving purely mathematical reasoning, of their impossibility. The assumption that they can be solved leads to a contradiction. (Prof by *reductio ad absurdum.*)

Why is it that an angle can be bisected but can not be trisected by elementary geometry? Because the first problem involves merely square roots and the latter cube roots, and only square roots can be constructed exactly with ruler and compass, that is, by a finite set of straight lines and circles.

Why is it that a regular polygon of 3 sides or 5 sides or 17 sides can be constructed, but not a regular polygon of 7 sides or 11 sides or 13 sides? Exactly the same reason applies, though the algebraic reasoning is somewhat more complicated.

A square can be duplicated, namely, by drawing a square on the diagonal of the given square; but a cube can not be duplicated because the cube root of 2 is involved. (In space of four dimensions, I may remark, the figure corresponding to a cube, called a "tessaract," can be duplicated because the fourth root of 2 can be written as the square root of the square root of 2.)

Why is it, finally, the circle can not be squared, and can not be rectified, that we can not find a square of the same area, or a straight line segment of the same length? Because in both cases the Archimedean number $\pi$ (which is defined as the ratio of circumference to diameter) is involved, and this number, since it can not satisfy any algebraic equation with integer coefficients, as proved by Lindemann, is surely not expressible by the rational operations or the extraction of square roots; and only these operations can be translated into an equivalent ruler and compass construction. The parabola is a more complicated curve than a circle; still the area of any parabolic segment can be found in rational form, and hence the curve can be squared.

Another subject of interest is the calculation of the number $\pi$, a number which may be called the most important number in the whole history of mathematics. It is approximately equal to 3, as stated in the Bible. A better approximation, known to the Egyptians, was 3.16. Archimedes found the approxima-

tion $3\frac{1}{7}$ by considering inscribed and circumscribed regular polygons of 96 sides. The familiar decimal 3.1416, used in our school books, was known at the time of Ptolemy (150 A. D.). Theoretically we can use Archimedes' method to calculate the value of $\pi$ with any degree of approximation by increasing the number of sides of the polygon, although the requisite calculations become very cumbersome. During the Middle Ages such calculations were made; but after the invention of the calculus by Newton and Leibnitz, very efficient methods were found, depending upon convergent infinite series, by which it was possible to carry out the result to many decimal places.

Here is the record of progress. In 1596 a Dutch mathematician, Ludolph van Ceulen, calculated 35 decimal places, in fact, the 35 digits were carved on his tombstone in a Leyden church. The Germans still call the number the Ludolphian number. This name is not used in other countries. I would like to suggest a name which I think would be the best, namely, I suggest calling $\pi$ the *Archimedean number*. I feel sure that Archimedes deserves this honor even at this late day.

In 1699, an Englishman named Sharpe calculated 71 decimal places. In 1824 a German, Dase, a lightning calculator employed by Gauss, worked out 200 places. In 1854, Richter computed 500 places. In 1873, an Englishman named Shanks calculated 707 places. This is still the world's record, and if any American wants to become famous, let him beat this record, let him calculate 1,000 places for good measure. It would perhaps involve 10 or 20 years of calculation, but that does not seem like waste of time in comparison with the billions of hours spent by millions of people on cross-word puzzles and contract bridge. A survey of the mental energy wasted by the inhabitants of this planet would be interesting. Perhaps it would be sufficient if concentrated on the number $\pi$, for the computation of a million or a billion decimal places.

Of course, such a calculation would not be of any conceivable practical use in applied science. We never need more than perhaps 10 decimals. Professor Newcomb remarked, "Ten decimal places are sufficient to give the circumference of the earth to the fractionth of an inch, and thirty decimals would give the circumference of the whole visible universe to a quantity imperceptible with the most powerful microscope."

But still the Archimedean constant, as I like to call it, is the most famous number and the most important number ever conceived by the human race in its centuries of thinking, and therefore, this particular number should be calculated to many places. We know *a priori* that the decimal will never end, because it is known that the number is irrational and in fact transcendental.

The efforts of computers, like Shanks, are of value chiefly in showing the superiority of modern analytical methods over ancient synthetic methods. The results of these extended calculations reveal nothing concerning the real nature of $\pi$, nothing as to whether it is rational or irrational, nothing as to its transcendental character, nothing as to whether it is constructible with ruler and compass. The familiar number $\sqrt{2}$, when written as a decimal (it has perhaps never been computed to more than 200 places), would appear just as complicated, for it never ends and never repeats, and there is no known simple law giving the succession of digits: yet this complicated decimal is easily obtained exactly by a ruler and compass construction, namely, by drawing the diagonal of a square whose side is unity. When the Greek philosophers discovered that $\sqrt{2}$ is not equal to any rational number

they celebrated the discovery by sacrificing one hundred oxen. How many oxen would they have sacrificed if they had made the more profound discovery that $\pi$ is a transcendental number?

If you want a simple example of a problem which is mathematically impossible take the question of finding two odd numbers whose sum is 21. It is clear that this can not be done, because the sum of any two odd numbers is always an even number.

A more difficult example of impossibility is that of satisfying the equation $x^3 + y^3 = z^3$ by any three positive integers. The impossibility was shown by Euler. The bisection of an angle or of a line segment is impossible with the ruler alone. (The bisection of a line segment is possible with the compass alone.) The solution of the general equation of fifth degree, in one unknown, is impossible by a finite combination of radicals. All these questions have been settled.

An unsettled question is the possibility of integers satisfying $x^n + y^n = z^n$. Another is the possibility of coloring all maps in a plane, or on a sphere, by means of not more than four colors.

The three most famous difficult numbers in mathematics and physics are the Archimedean constant $\pi$, the Napierian constant $e$, and the Eulerian constant $\gamma$. The first two of these are known to be transcendental (Lindemann, 1882, and Hermite, 1873) and are related by the marvelous equation $e^{i\pi} + 1 = 0$. The Eulerian constant is suspected to be transcendental, but this has not yet been proved. For all we know it may be that it is rational or that it is constructible with ruler and compass. We do not know. I hope that some one in my radio audience will settle this question and thus become immortal.

# EXCAVATIONS AT UAXACTUN[1]

By OLIVER G. RICKETSON, Jr.
ARCHAEOLOGIST, CARNEGIE INSTITUTION OF WASHINGTON

In the New World three distinct aboriginal civilizations developed three apogees of indigenous culture. These are the Aztec in the Valley of Mexico, noted for their military organization; the Inca in the Highlands of Peru, whose despotic, if beneficent, paternalism permeated every fiber of their politico-social fabric, and the Maya of Middle America.

We may justly rank the cultural achievement of the last as intellectually the highest, in that their genius developed not only an accurate calendric system, whose numeration called for the independent invention of zero and place-numeration, but also the orderly development of a pleasing architectural style and its concomitant decoration. Their architecture never violated the principles governing proportion and mass; its decoration, even when it appears florid to Western eyes, observes the fundamentals of design, and in their handling of perspective, the Maya surpassed all the ancient civilizations of the Old World previous to the Minoan.

It is with a sample of this highest aboriginal American civilization, as exemplified in the ruins of Uaxactun, Guatemala, that we are here concerned. So great are the lacunae in our knowledge, however, that the original name of this site is forever lost to us. It was given its present name on May 5, 1916, by its discoverer, Dr. S. G. Morley, an associate of this Institution.

On entering A-Group the first object that met his eye was Stela 9, bearing the Maya calendric inscription 8. 14. 10. 13. 15. *8 Men 8 Kayab*—or June 10th, 68 A. D. Since this was the first monument bearing a cycle 8 glyph, Dr. Morley named the ruin "Uaxactun"—from the Maya *uaxac,* meaning eight, and *tun,* stone. It is the oldest dated stela so far discovered in the Maya area. The latest date found at Uaxactun corresponds to 639 A. D. So that we have here a dated span of 571 years; that is to say, a period three and one half times longer than the United States have existed as a free and independent country. Yet archeology has afforded us every proof that Uaxactun was occupied long before the erection of the earliest stela—just how long it is difficult to say, but the sixth century before Christ would be a conservative estimate. Since we have positive proof that the Maya reused stone stelae, effacing one date to set up another, this custom offers a partial explanation for the lack of earlier dated monuments; but perhaps a better explanation lies in the supposition that dates may well have been carved first on wood rather than on stone. With the climate of Yucatan such as it is we can never hope to find traces of these.

Before I describe the actual excavations themselves, permit me a moment to describe two basic factors—environment and race—an understanding of which is necessary for a clear comprehension of the situation.

Environment is a basic factor which can not be ignored. As you are all aware, the peninsula lies within the tropics; the year is characterized by two seasons, the "rainy" and the "dry." Since the whole region is composed entirely of porous coralline limestone, permanent surface water is rare, despite a heavy rainfall; in fact, the present sur-

[1] A lecture delivered at Carnegie Institution of Washington, November 3, 1931.

face-water supply is so scant that it could not have met the needs of the ancient Maya during the dry season when their population was at its peak.

Various theories have been advanced to explain this condition, of which the most convincing is that of C. Wythe Cooke after a visit to Uaxactun this year. This theory is that the present-day *bajos* or logwood swamps, covering about 40 per cent. of the terrain, were formerly shallow lakes. The rapid erosion of the surface soil, following deforestation by the Maya, has silted up these lakes. Beyond the geologic evidence supporting this theory, namely, that the mud of these swamps is composed of black carbonaceous clay and disintegrating limestone—we should remember that the district itself is called the "Peten," a word meaning "lake" in Maya—and that the silting up of these former lakes would react very unfavorably upon the environment of the ancient inhabitants in at least two ways: first, because the origin of the silt is the surface soil of the higher land, composing the terrain suitable for agriculture. Its complete denudation would mean crop-failure and the consequent collapse of a civilization based on corn; and second, because the transformation of a lake into a morass not only eliminates rapid communication and easy transport by canoe, but changes the whole aspect of the region and renders land-transport well-nigh impossible by the development of such extensive swamps that they can not be avoided and must be crossed.

The normal increase of population is sufficient to account for a slow but steady expansion in search of new land; if, in addition to this population increase, we have also the progressive onset of these

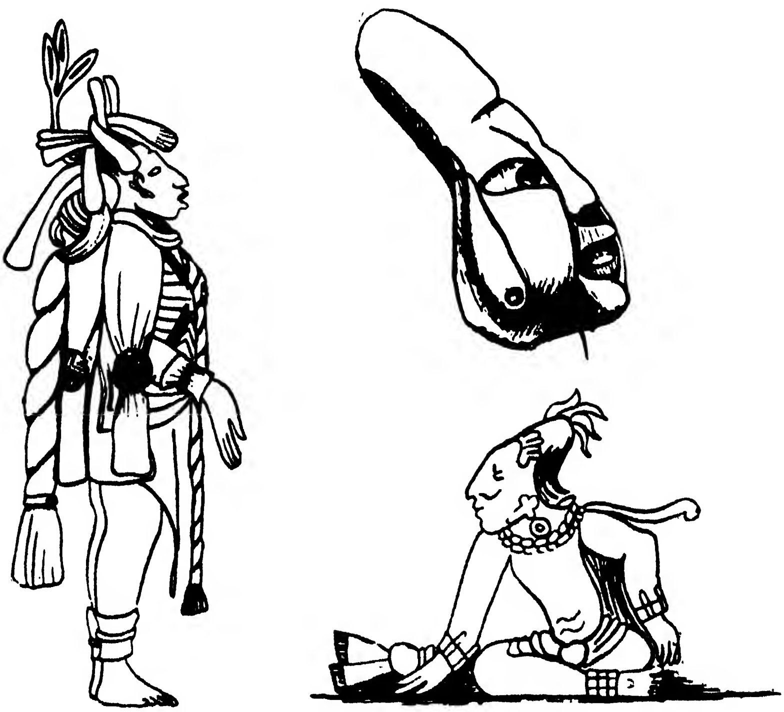


FIG. 1. PRIMITIVE TYPE FIGURINES

SHOWING FLATTENED FOREHEADS CHARACTERISTIC OF ANCIENT MAYA SKULLS. UPPER RIGHT—FROM BLACK DIRT STRATUM, UAXACTUN. AT LEFT AND LOWER RIGHT—FROM PALENQUE.

mutually interactive conditions, soil-denudation and lake-silting, we have a condition wherein expansion will be under forced draught, so to speak. This expansion, however, is no more of an exodus than was our own westward expansion across the Great Plains in the nineteenth century.

The sharp division of Maya history into two epochs—a so-called "Old Empire" in the south, abandoned in the seventh century A. D., to be followed later by a "New Empire" in the north, will have to be revised in the light of our present knowledge. The earlier centers were not abandoned; they merely yielded their prestige to new rivals. Incidentally, we should also explain that Maya ruins are not the remains of extensive cities; the Maya were not an urban people, but agriculturists. Even in the large, multi-chambered buildings of northern Yucatan there would not be housing facilities for a large population.

The ruins that we see to-day are the civil and religious centers to which the surrounding farmers flocked on market- and feast-days. Proof of this statement is evidenced by the fact that the low platforms forming ancient house-mounds extend throughout the jungle in every direction and without demarcation between one center and another.

By taking a sample count of these mounds and allowing the jurisdiction of such a center as Uaxactun to extend ten miles in every direction, we arrive at the conclusion that the population could not have been less than 48,000, providing that only 25 per cent. of the house-mounds were simultaneously occupied. If all the arable land were equally divided among all the house-mounds, each householder would own a lot 125 yards square. With intensive agriculture, such a lot would produce sufficient, and more than sufficient, corn, beans and squash for one family.

Our second basic factor is race. We definitely know that at Uaxactun we are dealing with a Maya race pure and simple. No evidence is at hand that any other type ever occupied this site. Such skeletons as have been encountered indicate that the individuals were markedly brachycephalic, of relatively light skeletal set-up and of equal stature with living Maya stocks as found in northern Yucatan and the Highlands of Guatemala to-day.

Two wide-spread characteristics of ancient Maya skulls are also seen at Uaxactun—fronto-occipital deformation, in which the forehead is purposely flattened (see Fig. 1), and the filing of the incisor teeth. We therefore assume, in the light of our present knowledge, that the first and original settlers of Uaxactun were of Maya stock, no evidence of a preceding race of inhabitants ever having been discovered. Not only is there no archeological evidence, but in the Book of Chilam Balam of Chumayel, which recounts legendary lore of the Maya, there is this statement in regard to the arrival of the Mayas. "They named the district, they named the wells, they named the region, they named the land, because no one had arrived here, here in Ucalpeten, when we arrived here." If this is the case, then, the living Maya can claim 2,500 years of continuous residence in the Peninsula of Yucatan, during which time the majority of their race has maintained its physical characteristics even up to the present day, and this in spite of the shock of the Spanish Conquest.

With these two factors in mind, let us now turn specifically to the ruins of Uaxactun themselves. These lie in the north central portion of the Department of the Peten, Guatemala (see map, Fig. 2) at the geographic center of the Yucatan Peninsula, in a dense high jungle which is to-day completely devoid of all permanent human habitation between

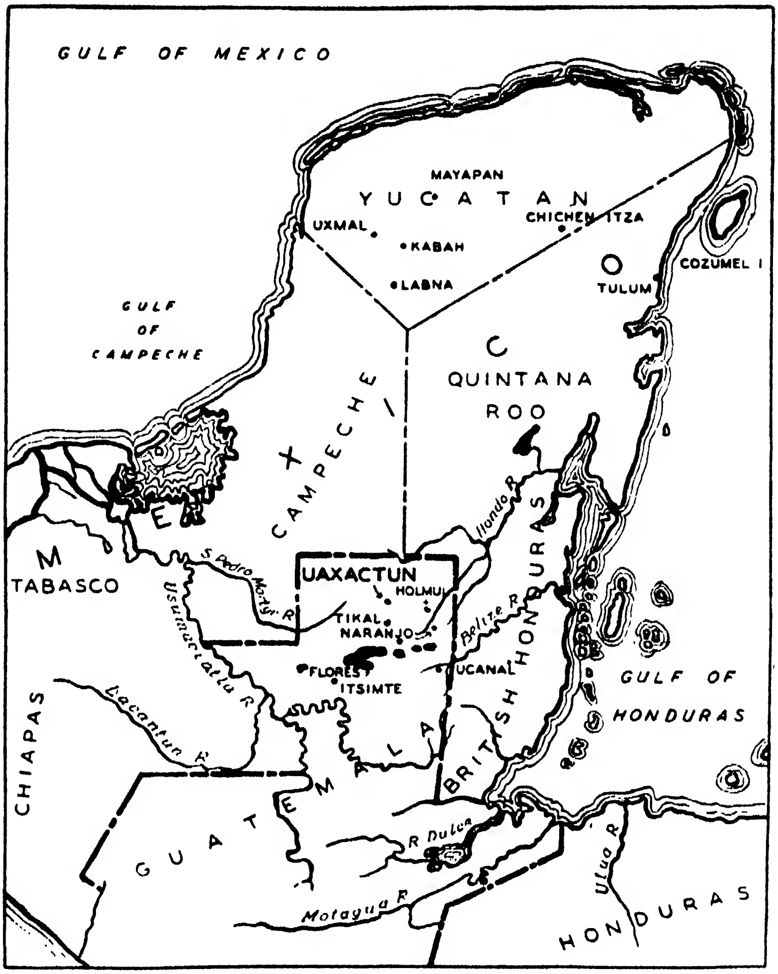



FIG. 2. SHOWING THE LOCATION OF UAXACTUN, GUATEMALA

SITUATED AT THE GEOGRAPHIC CENTER OF THE YUCATAN PENINSULA, IN A DENSE, UNINHABITED JUNGLE.

Peto, Yucatan, on the north and Flores, Guatemala, on the south.

So difficult are the conditions of travel that we may safely say the only people who penetrate the region are archeologists in search of ruins and chicle-bleeders in search of the indispensable ingredient of chewing-gum—the gum derived from the latex of the sapote tree. Although Uaxactun lies only 120 miles in an air line from Belize, British Honduras, yet the journey generally consumes a week or more—three or four days to ascend the Belize River in a 60-foot launch, and five days riding a mule as it alternately flounders through logwood swamps or crawls along the tortuous trails at the bottom of the jungle.

Twelve or fifteen miles is considered a day's journey during the "dry" season—less when the rains render the trails barely passable. The day's journey is also controlled by the location of *aguadas* or water-holes, for this is a country where running streams and springs are unknown, and camp must

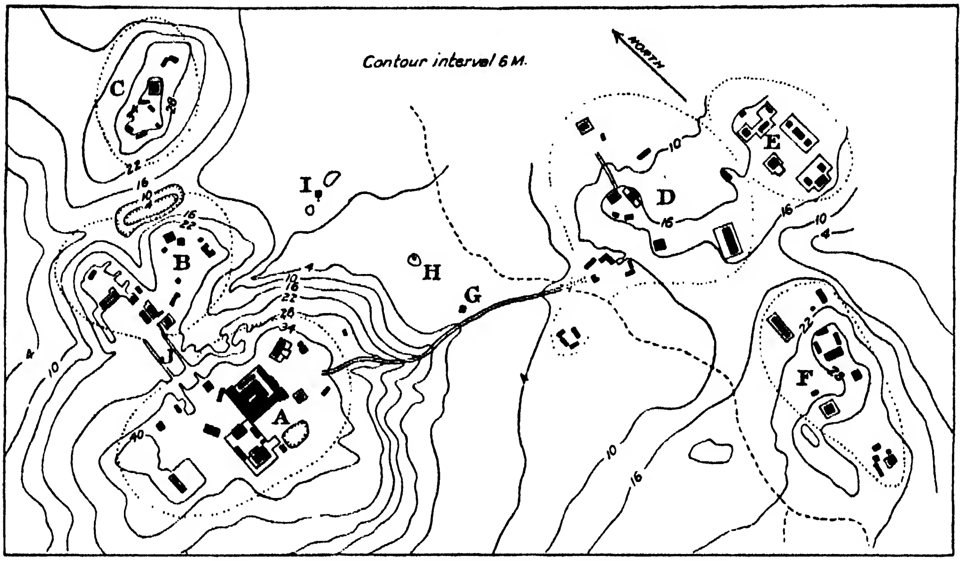



FIG. 3. MAP OF UAXACTUN (AFTER BLOM)
SHOWING: A, B, C, D, E, F, IMPORTANT GROUPS OF STRUCTURES; G, LABORERS' CAMP; H, AGUADA; I, STAFF HEADQUARTERS.

be made at water, of course. Perhaps the strongest impression the jungle makes on the outsider entering it for the first time is a sensation akin to suffocation—not from the heat, because the sun never penetrates the bottom, but from the subdued, green light and the still, silent air, unruffled by the slightest breeze.

Contrary to popular opinion, the monotony of the jungle trail is seldom broken by animal life, if we except the wail of the howler monkey. Although there are two of the large cats, the jaguar and the puma, and several of the small, such as the ocelot, these are nocturnal, as is also the largest denizen, the tapir. Two kinds of deer occur, and various small mammals, such as the armadillo, the agouti, the coatimundi and the more rare kinkajou.

On the other hand, bird-life is teeming, and contains one unique species not seen elsewhere—the beautiful ocelated turkey of Yucatan. Snakes, though well represented, find much of the country too wet; the best-known species of poisonous snake include the fer-de-lance, the tropical rattler and the coral-snake, but, again, contrary to popular opinion, these do not offer any particular hazard, and snake-bite would result only from treading directly on one. In fact, life in the jungle is a great deal safer than in one of our modern cities—the only enemies being malarial fever and intestinal infections, neither of which are even remotely liable to prove fatal with our present-day medical equipment. I may add, however, that if the safety-factor compares well with that of our modern metropoli, the comforts certainly do not. There is no more comparison between a Pullman and a pack-train than there is between a modern hotel and a bush *champa* (lean-to).

But we are digressing from our main subject; the map of Uaxactun (see map, Fig. 3) will show us that these ruins occupy the artificially flattened tops of natural hills, as is so characteristic of Maya sites in the Peten. More or less

centrally located may be seen the Main Aguada, north of it the Institution's field headquarters and south of it the laborers' camp. On the west, crowning the highest eminence, is Group A—here we have a standing building A–XVIII not of a temple but of a domiciliary type facing the East Plaza; the South Plaza bounded on the north by an entirely fallen but extremely massive and complex structure, A–V, containing 3 sunken courts; on the east by the South Terrace; on the west by the South Court, and on the south by the natural slope of the hill.

The South Court, already mentioned, is in itself a complete temple-plaza unit. Its chief temple, A–I, surrounded by 9 stelae, is the site of an important pottery cache which I will describe later on. North of it lies the Main Plaza, in which stands Stela 9—bearing the earliest date, 68 A. D.—from which extends an artificial causeway along a natural ridge to Group B.

This group, as can be seen, occupies the double top of a forked hill—the western plaza is called the Main Plaza, the other the eastern. B-Group stands 10 meters lower than A-Group. It is composed of large low mounds, of secondary importance to A-Group.

The third group, C, is an irregularly oriented collection of 9 mounds, crowning the top of a hill northeast of B-Group, and separated from the East Plaza of the latter by a steep-sided ravine. It contains no stela.

These three groups comprise the portions of Uaxactun west of the aguada. East of it are the two widely scattered groups D and F and the compactly built temple-plaza unit called Group E, or the Group of the Solar Observatory. This latter is the site of the excavations carried out by the institution during the past six years, and was chosen for two reasons. (1) The three stelae in its plaza, though not the earliest, still bear very early dates—98 A. D. and 235 A. D. (2) Frans Blom, who visited Uaxactun for the Carnegie Institution in 1924, noted that certain lines of sight from Pyramid VII to Pyramids I, II and III, respectively, corresponded very closely to the amplitudes of the sun at the solstices and the equinoxes. Excavations have proved that the positions of these temples are closely related with these four cardinal markers of the year,

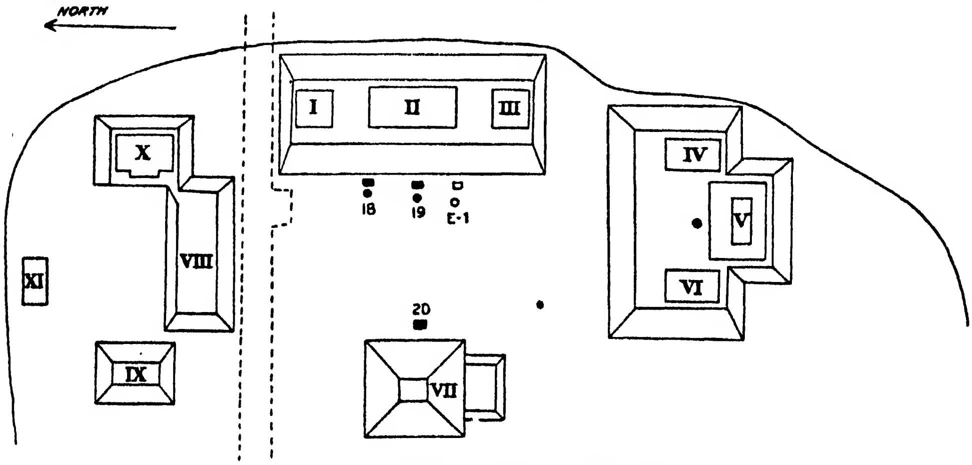



FIG. 4. GROUND PLAN OF GROUP E

SHOWING LOCATION OF THE MAIN TRENCH. THIS GROUP COMPRISES ELEVEN MOUNDS, GROUPED AROUND ONE MAIN PLAZA.

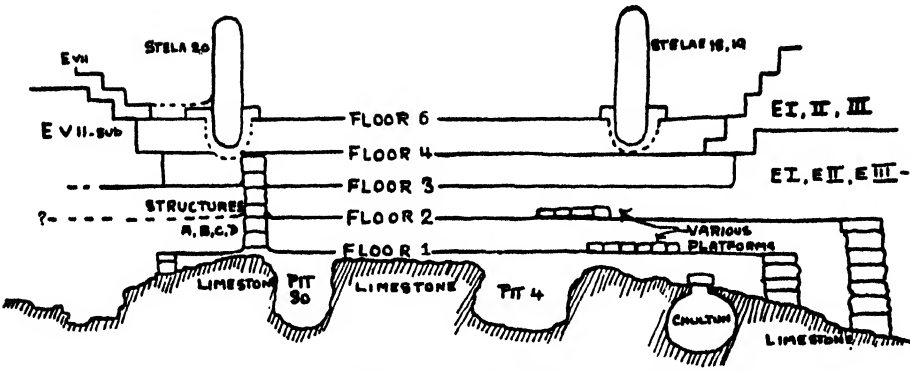



FIG. 5. DIAGRAMMATIC CROSS-SECTION OF E-PLAZA

SHOWING SUPERPOSITION OF PLAZA FLOORS. FLOOR 5 HAS BEEN OMITTED. STELA 20, DATED 235 A. D.; STELAE 18, 19, DATED 98 A. D.

probably for purposes of geomancy rather than for actual observation in a modern astronomic sense.

The group was also chosen for excavation because of its compactness, which would permit its thorough examination in a period of five years.

An examination of the map (Fig. 4) shows that this group comprises eleven mounds, grouped around one Main Plaza and a smaller North Court. All but one are in complete ruin.

Temples I, II and III surmount a 15-foot mound, closing the main plaza on the East; Temples IV, V and VI surmount a similar mound, closing the main plaza on the south; Pyramid VII stands solitary on the west. It was from a position on the stairway leading up to this structure that the lines-of-site to I, II and III marked the cardinal points of the year. On the north the plaza is closed by a long, enigmatic mound, VIII, whose adjacent structures, IX on the west and X on the east, enclose, with the aid of Pyramid XI on the north, the North Court. Temple X is partially standing, a condition found elsewhere in Uaxactun only at A–XVIII.

Temples I, II and III were those first excavated. These were found to consist of an outer and inner room, the latter invariably containing a low masonry altar. In the floors of all these temples were small circular cists with caches of two types; one type consisting of two flat-bottomed redware dishes with flaring rims, laid the one inverted over the other, containing in the space between them a human skull. Inasmuch as the first few cervical vertebrae were found beneath each skull, it is evident that the head must have been severed from the body—and that we therefore are not dealing with a secondary skull burial, but with human sacrifice.

The second type of cache consisted of a small cylindric jar, generally lidded and barrel-shaped, which often contained a red powder—hematite—or a stone object. The most striking object found in this type of cache was a small archaic green mudstone human figurine, represented as squatting. This figurine has been called crude because early and therefore primitive, and it has been called crude because late and therefore degenerate. There is no doubt in my mind that it is primitive, but its manufacture long anteceded the erection of the temple in which it was found.

Opposite the three temples just described stood Temple VII. This steep-sided pyramid originally stood 50 feet high, but the dilapidated character of its masonry precluded the determination of

any architectural features other than that a stone-balustraded stairway once ascended its east face; just how far we do not know, for unlike the usual Maya pyramid, this was not a substructure mound with a flat top whereon a temple was erected. It continued up to a more or less sharp peak (Fig. 7).

As excavations proceeded around the base of this pyramid in a vain effort to find definite remains of wall stones *in situ,* a hard, perfectly preserved stucco surface was found directly beneath it, which upon further investigation revealed itself as an earlier pyramid completely covered over and preserved by the later one. This pyramid was called E–VII–sub and was eventually found to consist of a low terraced platform ascended on all four sides by stairways (Fig. 8). On its top sat another platform, access to whose top was had by only one stairway on the front or east.

All these stairways—five in number—were flanked by grotesque stucco masks built up over stone cores—the four

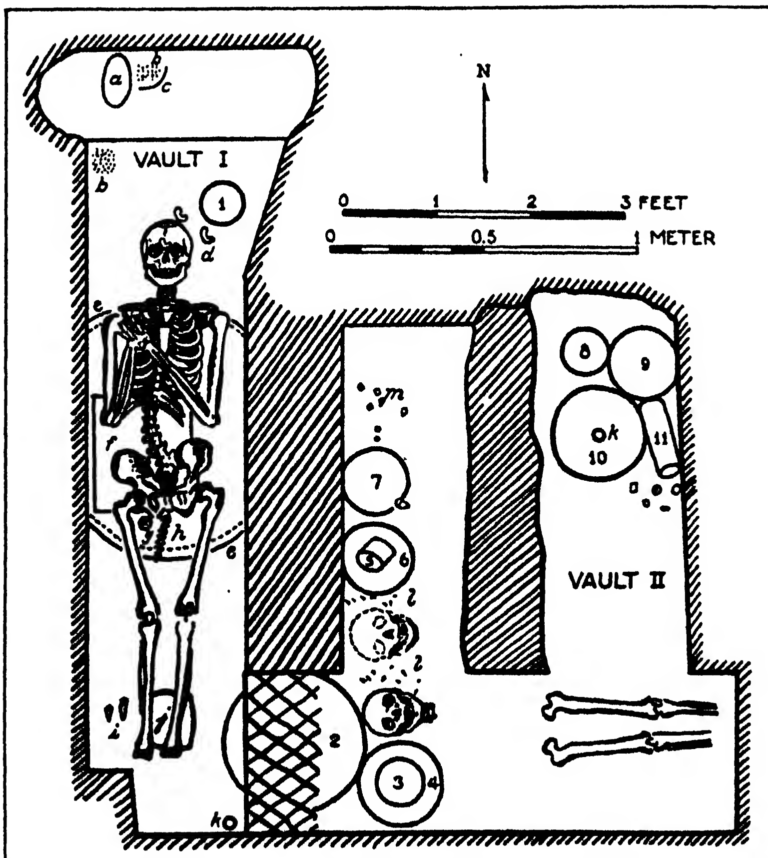



FIG. 6. DIAGRAM SHOWING THE BURIAL VAULTS AND THE LOCATION OF THEIR CONTENTS.

A, Fragmentary skull of large mammal. B, B, Carved pieces of bone pierced for use in a necklace. C, Fragment of pottery vessel. D, Sea shells. E, E, Area of charred wood underlying skeleton. F, Hole below charred wood area. G, Large jade bead. H, Tail of sting-ray. I, Deer antler. J, Large rectangular bone (turtle?). K, K, Jade beads. L, L, Human teeth. M, Iron oxide. 1–11, Pottery vessels.

main stairways of the supporting platform having two such masks on either side, the single stairway of the upmost platform having but one. There are therefore 18 masks in all, the general design of which does not conform to what we may call Classical Maya, but is yet so Maya in feeling that we have referred to it as Primitive Maya. These masks, roughly eight feet square, all represent grotesque human faces with open slit-like mouths in which exaggerated teeth are shown. Their general expression is one of ferocity. They have all a rolled ornament over the nose, and a broad band across the face at the level of the nostrils, reminiscent of a nose plug. Perhaps they carry a suggestion of the rain-god Tlaloc. Masks of similar motif, but broken down into greater conventionality, have been reported by Merwin from Holmul, a near-by ruin with which certain periods of Uaxactun pottery are to be associated, as we shall see.

Important as this discovery of an extremely early type of Maya architecture may be, the scientific importance of less spectacular excavations is even greater. This resulted from the sinking of an elaborated network of trenches into the very plaza itself. The photographs of these trenches will give some idea of their size—the first one, that of the main north-south trench—shows us how this trench appeared at the conclusion of the 1929 season (Fig. 9). It has been dug down through six superimposed plaza floors, the one overlying the other.

The six plaza floors extending across the plaza were found to overlay a deposit, varying in depth, of a black earth (Fig. 5). Beneath this was the basic limestone, so that we are more than reasonably certain that in this case we have reached bedrock.

The inferences from these trenching operations may be summarized as follows:

(1) Pits and bottle-shaped chambers called *chultuns* were found artificially excavated by the Mayas in the solid limestone at depths of 15 feet below the present plaza surface.

(2) All soil from limestone up to the present surface bore traces of man's presence in one form or another—such as burials, worked shell or flint or obsidian, and broken fragments of pottery.

(3) The lowest layer, the so-called Black Dirt, underlying the main plaza floors, is a refuse bed—a typical midden type of deposit formed by the gradual accumulation of vegetable débris, such as thatching for roofs and the débris from long occupancy by man.

(4) The lowest plaza floor is to be associated with a plaza much smaller, as compared with the latest plaza; on it are rectangular platforms presumably the foundations for the earliest structures. Whether these were of wood or of stone, they had been razed to make way for the later plaza expansions.

(5) The six plaza pavings occur directly superimposed the one upon another. From the lack of débris accumulation between these superimposed floors we assume that the period involved in their construction need not have been long. As compared with the Black Dirt accumulation, the period may well have been relatively short.

(6) The period of construction of E–VII–sub corresponds with the laying of the second and third floors of the plaza.

(7) The period of construction of E–VII outer corresponds with the laying of the fourth, fifth and sixth floors.

(8) The erection of Stelae 18 and 19, both dated 98 A. D., and that of Stela 20, dated 235 A. D., loses much positive significance, in that their floor-relations indicate these monuments to have been

erected simultaneously. In other words, the earlier ones must have been removed from their original locations. In the case of Stela 20, dated 235 A. D., we can say with some assurance that it probably marks the latest possible date for the construction of E–VII outer.

The true significance of these excavations, however, lies in the definite development of the first pottery stratification for this area, as worked out by Mrs. Ricketson. And here we are back again on firmer ground. There are three main types:

I. Uaxactun I—an early or "archaic" type. This type is found only in the Black Dirt stratum and is characterized by the following types:

(a) large ollas of unslipped orange-red ware, design in brown wash, thinly applied.
(b) small ollas of polished black ware with incised cross-hatchings generally in diamond and half-diamond designs.
(c) Round bottomed bowls, some spouted, with horizontal fluting around the neck.
(d) Flat-bottomed dishes, having everted rims with horizontal, parallel incisal lines.
(e) figurines—of definitely "archaic" characteristics, which are always modeled, never moulded or cast.

II. Uaxactun II. Middle Period. This corresponds to Holmul III. It is characterized by wide-mouthed dishes, with a basal bevel or flange, in polished black ware or with complicated polychrome designs on the exterior.

III. Uaxactun III. A late period. Corresponds to Holmul V. It is characterized by:

(1) tripod dishes, with rattle legs;
(2) shallow plates (some with tripod

FIG. 7. TEMPLE E–VII, UAXACTUN

AT CLOSE OF THE 1927 SEASON. THE TWO MASKS VISIBLE BELONG TO AN UNDERLYING PYRAMID, E–VII–SUB. STELA NO. 20, DATED 235 A. D., IS SEEN AT FRONT.

support) with polychrome design on interior;
(3) cylindrical vases with polychrome design on exterior, consisting of glyph-band and life figures.

This pottery sequence at Uaxactun seems to indicate an early influence from the south, Salvador and Nicaragua, a local development, and a later influence coming from the north or highlands of Guatemala. The nearest relationships for the Uaxactun I figurines are seen in those from the Ulua Valley, though there is also a resemblance, not so close, with the figurines from the Finca Arevalo, Guatemala.

When I mentioned Temple A–I, I said that it was the site of an important pottery cache found by Mr. Robert Smith in 1931. The cache consisted of eleven magnificent polychrome pots from a grave vault (Fig. 6). These are all of Uaxactun III period, that is, polychrome designs often with glyph-bands and life figures. I shall here describe seven of the more important of these vessels.

The first of these vessels is a simple bowl, six inches in diameter, and 3.6 inches deep, of polished orange-red ware with a conventionalized design in red and brown in four bands horizontally around the rim and sides; the second, a similar polychrome bowl, 6 inches in diameter and 6 inches deep, with the addition of black to the colors already mentioned. The third is a polychrome

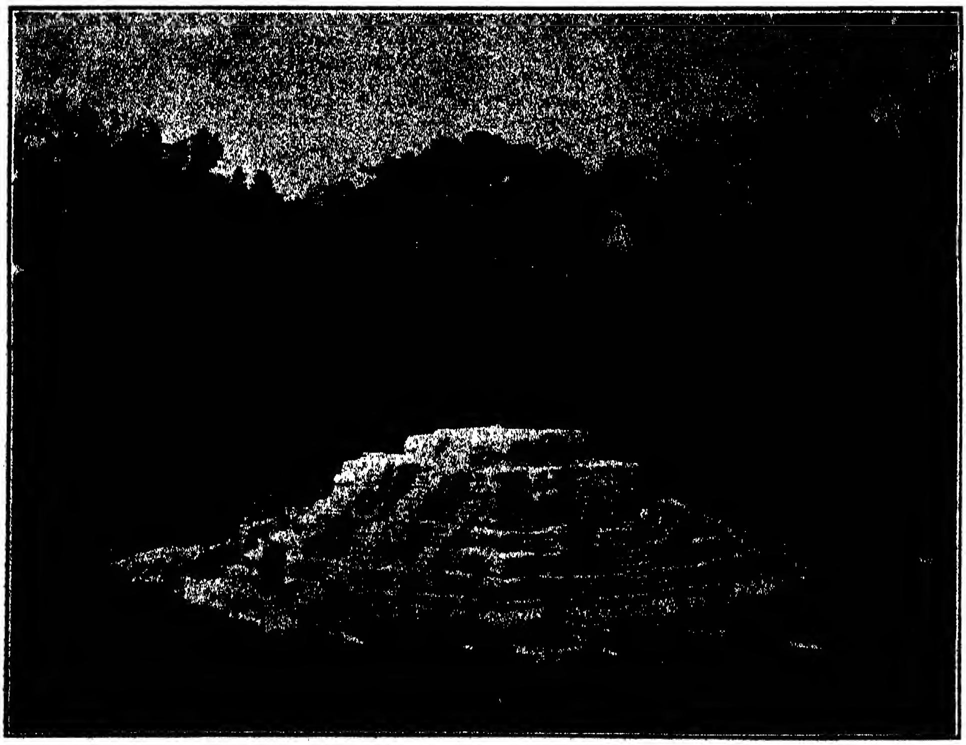


FIG. 8. E–VII–SUB.

THIS PYRAMID WAS BUILT OF UNCUT STONE AND FACED WITH DAZZLING, WHITE STUCCO. FOUR MAIN STAIRWAYS LEAD TO THE TOP. FLANKING THESE ARE COLOSSAL MASKS OF FINE, LIME STUCCO, FASHIONED IN THE LIKENESS OF GROTESQUE HUMAN HEADS. STELA E–20, AT LEFT, BEARS THE DATE OF 235 A. D.

FIG. 9. TRENCHES IN E-PLAZA
AT THE CLOSE OF THE 1929 FIELD SEASON. LATER THESE WERE DUG DOWN THROUGH SIX SUPERIMPOSED PLAZA FLOORS.

bowl, 7.5 inches in diameter and 2.7 inches deep, but with only black and red on the orange background, and with two vertical areas of red instead of the horizontal bands seen on the others.

A fourth vessel from this cache is a shallow bowl with an orange slip on the inside, unslipped and unpainted on the outside, measuring 12.25 inches in diameter and about 3 inches deep. The painted design on the interior consists of a narrow black and a broader red band around the rim, and a central figure in red outlined with black which is not identifiable, though it has some resemblance to the head and forelegs of a turtle emerging from an area of red curlicues.

A fifth vessel is a shallow, flanged tripod dish, 18.2 inches in diameter, unslipped and unpainted exteriorly but bearing on the interior an elaborate design in red and black on a buff background (Fig. 10). The flattened, slightly everted rim (2″ wide) is painted solid red for half the circumference; the other half has black spots, simulating the spots of a jaguar, on buff. Within the rim, the concavity of the plate pitches more steeply for a distance of two inches. It is set off from the rim proper by a heavy black line. This surface is painted solid red for half the circumference; the other half shows five series of hieroglyphs outlined in black but painted red.

Within these two rim areas are two concentric heavy black lines which enclose the main artistic effort . . . a boldly, if carelessly, executed picture, also in black and red, depicting full face on the right a man in regalia with a javelin or staff, looking left. The body of a serpent divides the remaining surface into an upper and a lower portion. In the upper portion, facing left, are four human figures in profile. The first on the right carries a stick; the second holds the tail of a jaguar whose body fills the lower left quadrant of the dish, below the serpent's body. Both of these human figures are standing. The third

FIG. 10. A SHALLOW, FLANGED TRIPOD DISH FROM VAULT II

ITS EXTERIOR IS UNPAINTED; ITS INTERIOR BEARS AN ELABORATE DESIGN IN RED AND BLACK ON A BUFF BACKGROUND.

and fourth figures, however, are kneeling and hold before them in their hands a monkey each.

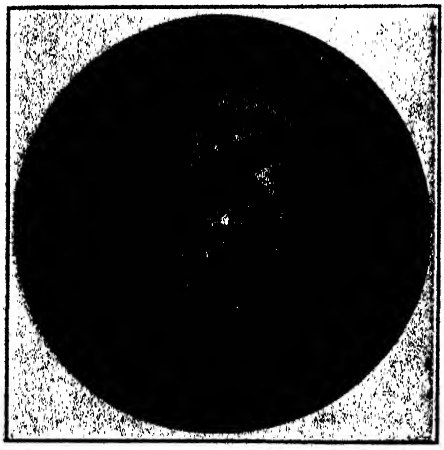


FIG. 11. A SHALLOW BOWL

14 INCHES IN DIAMETER, ALSO FROM VAULT II. THE FIGURE IS THAT OF A MAN POISED AS THOUGH ENGAGED IN A POSTURING DANCE. THE HOLE THROUGH THE MIDDLE INDICATES THAT IT WAS CEREMONIALLY "KILLED," POSSIBLY TO RELEASE THE SPIRIT OF THE VESSEL TO ACCOMPANY THE SPIRIT OF THE DEPARTED OWNER.

The lower portion of the dish depicts the body of the jaguar already mentioned on the left; another jaguar approaches from behind the large human figure in regalia, which we first mentioned as filling the whole right-hand area. Both jaguars give the impression that they are stalking or even springing at a central human figure, apparently unclad, which is shown in profile and head down between them, in what, for lack of a better word, we may describe as an acrobatic position . . . arm on the ground, head bent back so that the face looks to the left, the body rising in a column above, and the legs flexed at the knee so that the feet hang down.

As already said, the whole has been done with boldness; in spite of its obvious complication, it leaves small areas around the periphery blank; the scene depicted is certainly ceremonial, the full face figure on the right being the master of ceremonies, the "acrobatic figure" perhaps being a corpse thrown to the jaguars. If this figure represented a form of the Diving God, one would expect it to wear insignia. Tricklets of tears from its closed eye would seem to indicate that the individual was either dead or not enjoying the prospect.

A sixth dish, 14 inches in diameter, with tripod legs, also unslipped and unpainted on the exterior, shows a central human figure in red and black on an orange-buff background (Fig. 11). The rim area is demarcated by outer and inner concentric red and black borders, 1½ inches apart, containing between them a series of non-calendric hieroglyphs painted free hand in black.

The human figure represents a man standing erect, full face, toes apart, with a large non-feather headdress and a highly deformed skull. His left arm and shoulder are raised, the palm extending outward, the long fingers pointing down. His right arm, rigid, is held

down slightly away from the body, the hand and fingers bent inwards and upwards. Feet, legs, torso and arms are red; the face, except for the region around the eyes and mouth, which are orange-red, is left the buff color of the background, as are the thighs. These latter give the appearance of being clad in puffy doublets supported by black and red sashes whose half dozen ends swirl out around the legs. Nothing can describe the position of this figure better than to say that it probably depicts some posturing dance at a moment when the arm-action is semaphoric in its rigidity. That this piece was ceremonially "killed" is indicated by the hole in the center.

The most interesting vase from this cache, and the last, is a cylindric jar measuring 9 inches in height and nearly 6 inches in diameter (Fig. 12). It is slipped inside and out with a cream-white slip, and painted outside, the design showing against a red background. Around the rim, beneath a band of red .3 inches wide, is a cream-colored band .9 inches wide bearing hieroglyphic figures outlined in black and painted for the most part red, with some pale orange. Below this band there are represented six figures, five human and one jaguar. The chief figure is represented seated cross-legged on a dais, full face, but with the head facing left. Behind it stands a smaller figure, dressed in black, bearing before him as an offering some object in his hands. Behind this figure stands a third, larger one, bearing a ceremonial staff, which he holds over the heads of the other two; the staff carries a panache of feather work at the extremity and was intended perhaps for shade as well as for regalia of office. These three figures all face left; they are unfortunately in a poor state of preservation,

FIG. 12. A CYLINDRICAL JAR

9 INCHES HIGH AND NEARLY 6 INCHES IN DIAMETER, FOUND IN VAULT I. THIS PICTURE REPRESENTS IT AS CUT FROM TOP TO BOTTOM AND FLATTENED OUT. THE JAR IS DECORATED WITH A COMPLICATED DESIGN SHOWING AGAINST A RED BACKGROUND. NOTE THE DOUBLE ROW OF DATE GLYPHS AT LEFT OF THE SEATED FIGURE. THIS IS THE FIRST SERIES OF SUCH GLYPHS EVER FOUND ON ANY MEDIUM OTHER THAN STONE OR STUCCO. ACCORDING TO ONE SYSTEM, 120 B. C. IS THE DATE REPRESENTED; ACCORDING TO ANOTHER, 140 A. D. IS INDICATED.

the slip having peeled off, perhaps because this side was nearest the burial itself.

Facing them stand the other two figures, and the jaguar, sitting; but between the foremost of these figures and the chief seated figure we have already described is a double row of calendric hieroglyphs, eight in a column, or sixteen altogether. The first of the figures facing the seated figure is a man standing, with an elaborate feather headdress and a fringed apron-like garment extending from his neck to below his knees. His right forearm extends through this apron and he holds in his hand a small, tridentate object, the points down, resembling an eccentric flint. His skin is represented as painted black on the arm, legs and face, except for an area around the mouth, which is left cream. Behind him, as though attached at a point just below the shoulders, is a cruciform design representing a feathered serpent, whose head and jaws face left. Beneath and behind him the sitting jaguar is represented holding in his outstretched right paw two flaring rimmed dishes, the one inverted over the other, and tied together with a band.

The last figure is similar to the one last described, the essential difference being that he holds upright a plain staff in his right hand. His headdress involves a jaguar head as well as featherwork, and a less elaborate, conventionalized feathered serpent is shown behind him also, as though attached to the small of the back. All these figures stand on a narrow cream-colored band just above the bottom of the vase. Four series of non-calendric hieroglyphs are shown in juxtaposition to the various figures.

The calendric hieroglyphs, reading from left to right and from top to bottom, give us the date 7. 5. 0. 0. 0. 8 Ahau 13 Kankin. Unfortunately, this seventh cycle date can not be contemporaneous, because the vase belongs stylistically to the latest period at Uaxactun. We might infer then that the date referred back to some past event in history wherein two ambassadors appeared before a king or noble. But unfortunately the fifth katun of the seventh cycle does not fall on 8 Ahau 13 Kankin, so that it is quite evident that the potter himself made a mistake when he put on this Initial Series.

Maya hieroglyphs and their systems of bar and dot numeration being what they are, several solutions have been offered in an effort to determine the date that was actually meant. Dr. S. G. Morley adds one dot to the cycle, making it read 8. 5. 0. 0. 0; this falls on 12 Ahau 13 Kankin, so that the only other correction necessary is to change the one bar and three dots of the day-sign Ahau to two bars and two dots. This system has the merit of merely changing the numerations and not the glyphs, but on the whole it is very difficult for us, almost two thousand years later, to decide just exactly what date was meant, and, in this case anyway, the importance is not so great, inasmuch as the contemporaneity of the manufacture of the pot and the date 7. 5. 0. 0. 0 is out of the question.

The description of this cache concludes my remarks on the excavations carried out during the past six years at Uaxactun. I hope that the future excavations, which will be under the direct charge of Mr. Ledyard Smith, will uncover other caches of equal beauty and importance; perhaps it is one of the fascinations of archeology that nobody can predict what the removal of the next spadeful may reveal.

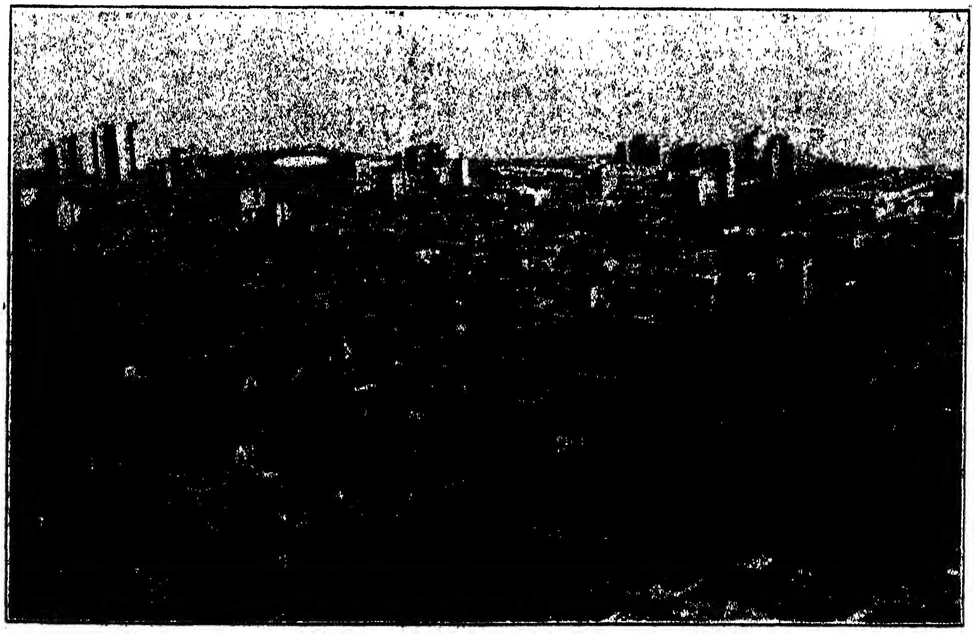
# THE PROGRESS OF SCIENCE

## THE CENTURY OF PROGRESS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

CHICAGO this summer is the Mecca of tourists from all over the world. Its Century of Progress Exposition, wonderfully planned and widely heralded, has aroused interest in every corner of the globe. Motor cars, trains, ocean liners, are bringing visitors to a huge metropolis that a hundred years ago was bare prairie.

The meetings of the American Association for the Advancement of Science at Chicago probably will be the greatest in the history of the association. The setting is perfect. This world's fair, more than any other, is dedicated to the effects of scientific discovery on the life of mankind. It is a fair that should awaken in the mind of the layman the necessity of scientific achievement far more emphatically than has any previous effort. In addition to the exposition, two large universities are cooperating toward the success of the meetings.

The exposition and the association are bringing as guests a long list of distinguished foreign scientists to contribute their views and researches at the meetings. An unusually large number of sessions will be devoted to invited papers by these and by scientists from North America. Every field of scientific work is covered, and the length of the program is such that the meetings will extend over twice the usual period. They will begin on the nineteenth and continue to the end of the month.



THE UNIVERSITY OF CHICAGO FROM THE AIR

THE UNIVERSITY BUILDINGS AND GROUNDS HAVE BEEN OUTLINED BY PARTIALLY PAINTING OUT THE AREA SURROUNDING THEM. THE GROUP OF BUILDINGS AT THE LOWER LEFT-HAND CORNER IS DEVOTED TO THE MEDICAL SCIENCES. THE INTERNATIONAL HOUSE APPEARS AT THE EXTREME RIGHT, AND THE ISOLATED BUILDINGS ACROSS THE MIDWAY COMPRISE THE NEW DORMITORIES FOR MEN.

THE HALL OF SCIENCE AT A CENTURY OF PROGRESS, CHICAGO'S 1933 WORLD'S FAIR

WHERE THE MARVELS OF SCIENTIFIC PROGRESS IN THE LAST CENTURY WILL BE UNFOLDED. THE ABOVE PHOTOGRAPH SHOWS THE EAST VIEW OF THE BUILDING, AS SEEN AT NIGHT. THE TOWER IN THE CENTER OF THE PICTURE IS ILLUMINATED WITH NEON TUBES IN A MYSTERIOUS BLUE AND ROSE COLOR. IT CONTAINS IN ITS TOP A SET OF CARILLON CHIMES. TO THE RIGHT OF THE TOWER EXTENDS A WALL WHICH FORMS THE WEST EXTREMITY OF THE GREAT COURT. THE WING SHOWN AT THE EXTREME RIGHT HOUSES THE EARTH SCIENCES EXHIBITS.

THE FIELD MUSEUM OF NATURAL HISTORY IN CHICAGO

At this meeting, with the greatest number of affiliated societies gathered together in the history of the association, it is extremely difficult to pick out sessions that stand ahead of others in interest.

Perhaps the symposia of Section N—Medical Sciences—may be of most appeal to the general public. In one of these the progress of the past century will be reviewed by Dr. Morris Fishbein, speaking on "Frontiers of Medicine." Other participants will be Dr. Paul Dudley White on "Heart Disease" and Dr. Max Cutler on "The Conquest of Cancer."

Dr. Goldschmidt of Berlin, prominent authority on heredity and sex, is taking part in a symposium on "Heredity," whereas Professors Hill of London, Krogh of Copenhagen and Barcroft of Cambridge are giving talks on physiological subjects.

The many meetings of Section M and the affiliated engineering societies have caused the second week to be designated as "Engineering Week" and have induced the exposition to set June 28 as "Engineering Day." Attracting perhaps outstanding public attention among engineering papers will be those by Dr. A. P. M. Fleming of England on "The Industrial Development of the Century" and Dr. H. J. Gough on "Crystalline Structure in Relation to Failure of Metals, Especially by Fatigue."

Section L—Historical and Philological Sciences—holds on June 26 a symposium on "Nationalism," with guests and members speaking. "Imperialism, National and International Peace" will be discussed by Director Albrecht Mendelssohn Bartholdy, of the Institute for Foreign Affairs at Hamburg, Germany.

In the realm of pure, physical science the general session on the evening of June 21 may prove to be of greatest interest. Professor N. Bohr will preside. Dr. F. W. Aston of Cambridge, En-

ANOTHER VIEW OF THE HALL OF SCIENCE

THE SOCIAL SCIENCES ARE HOUSED IN THE LEFT WING. THE COURT ACCOMMODATES 80,000 PERSONS.

gland, will tell the "Story of Isotopes" and Dr. R. A. Millikan will speak on "New Light on Nuclear Physics." Other symposia on physical science with famous foreign and American speakers will in interest follow closely after this session.

On the same date will occur a joint meeting of Sections E, B, C and D with the American Physical Society to discuss "Measurement of Geologic Time." On the next day Sections B and D will meet with the American Physical Society and the American Astronomical Society in a symposium on "Spectroscopy and Astrophysics."

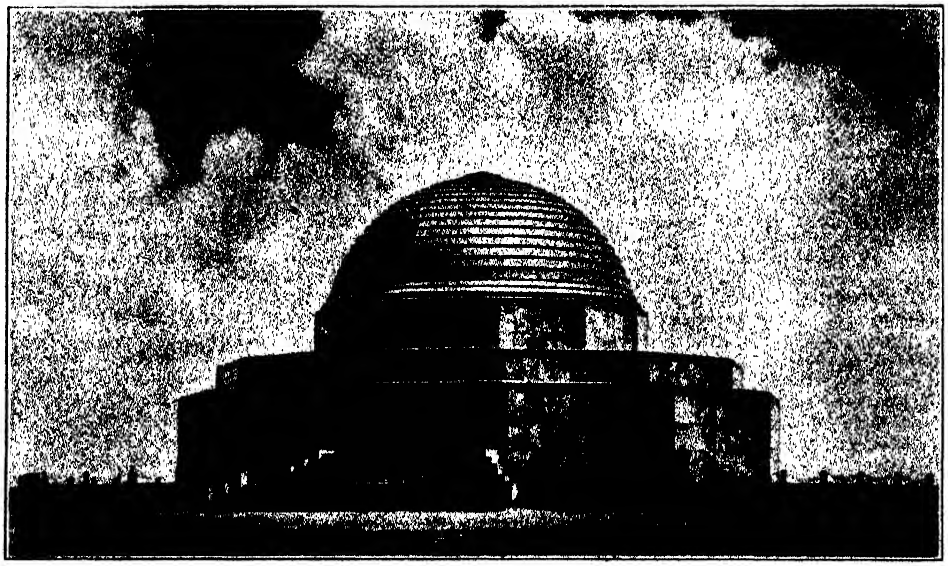
This brief summary of the meetings would be incomplete if the meetings of Section I—Psychology—were not considered. The names of the foreign guests alone are sufficient to indicate the interest. These include Professor Wolfgang Köhler of Germany, Professor Charles E. Spearman of England, Professor Henri Piéron of France and Professor Emilio Mira of Spain.

On June 23 there will be a general session on anthropology, held at the Field Museum. Director C. U. A. Kappers, of the Central Institute for Brain Research at Amsterdam, Holland, will speak on "The Anthropology of the Near East." Following this session the museum will hold an open house for the members of the association and their guests.

Dozens of other sessions would be well worth lengthy description. The fact that there are more than 300 pages in the official program testifies vividly to the inclusiveness of the meetings. It would be impossible for one interested in even the most narrow specialty not to find discussed subjects that are closely related to his special field.

On June 19 the Century of Progress Exposition is tendering a huge reception to the American Association for the Advancement of Science. This reception is in honor of the foreign guests. On other evenings during the meeting there are numerous lectures, banquets, symposia, etc. Special prevision is being made for the entertainment of wives of attending scientists.

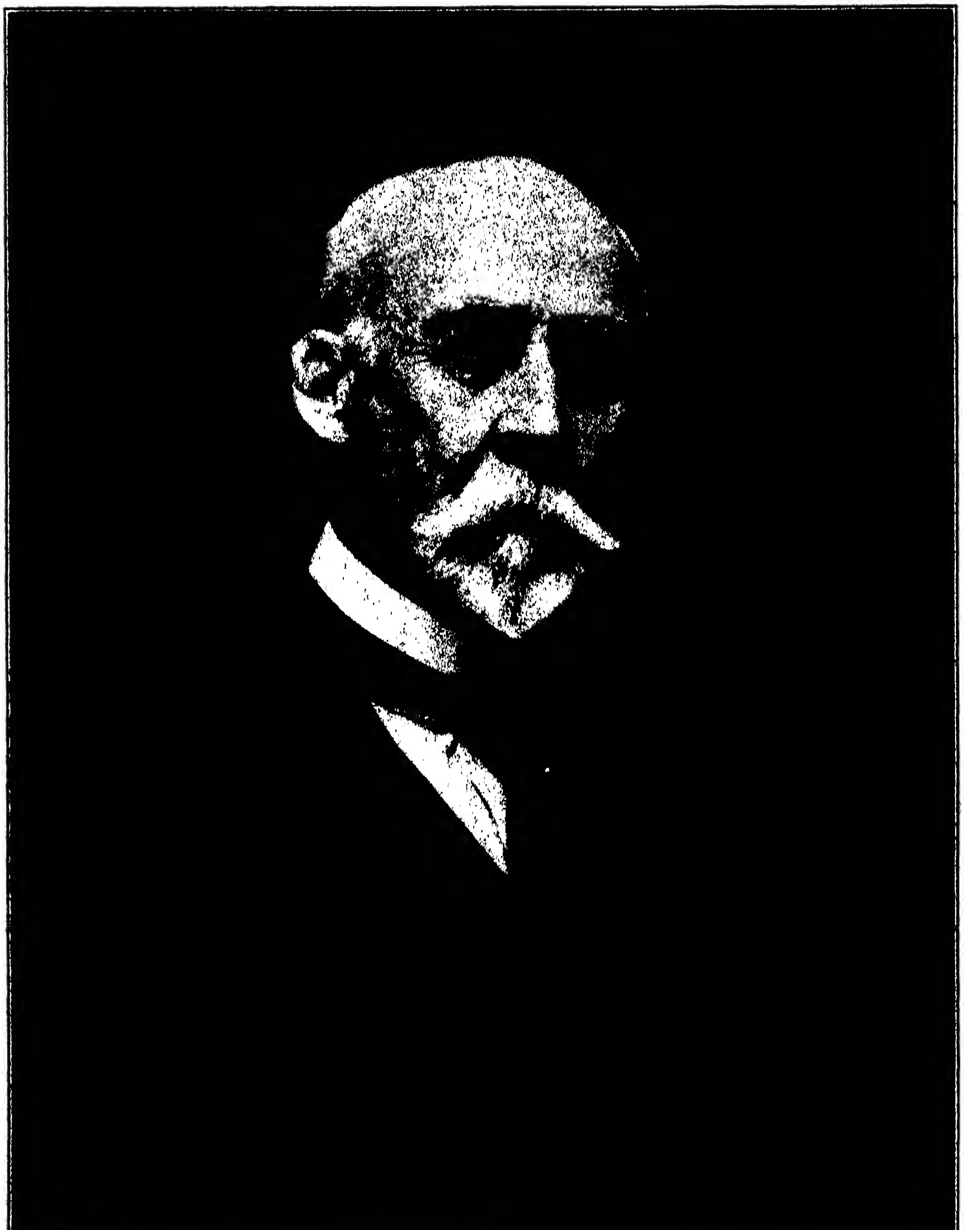
DINSMORE ALTER



—E. L. Fowler

THE ADLER PLANETARIUM

IN WHICH THE AMERICAN ASTRONOMICAL SOCIETY WILL HOLD SOME OF ITS SESSIONS.



WILLIAM HENRY HOLMES

THE DISTINGUISHED ANTHROPOLOGIST WHO DIED RECENTLY AT THE AGE OF EIGHTY-SIX YEARS.

CYRUS HALL McCORMICK

A. A. WEINMAN, SCULPTOR.

## THE INVENTION OF THE REAPER

THE problem of the harvest is one of immense antiquity. Millenniums before the written records of the race appear, our ancestors seem to have hacked with sharpened flint at the life-giving grain. Almost by the time of Christ, man was engaged in fumbling efforts to develop for this purpose some type of power other than his own. The dawn of the era of industrial mastery accelerated the attempt. In the last quarter of the eighteenth century and in the first quarter of the nineteenth, more than fifty known trials of this nature are chronicled.

Upon a quiet farm in the lower valley of Virginia, in the summer of 1831, the first definite success was realized. The inventor of the machine, later to be perfected into world-wide acceptance, was Cyrus Hall McCormick, then just twenty-two years old. The circumstances of his achievement add glory to what is probably the most significant aid to agricultural enterprise. Young McCormick did not live in a community marked by the contagion of industrial endeavor; he did not even know of the previous models brought out over the world. Stimulus had come, it is true, from his father's interest in fashioning machines, including experiments with a reaper. Chiefly, however, McCormick pondered in his own mind the difficulties and visualized in his own imagination the processes that might overcome them.

It could hardly be claimed that the reaper which was first publicly exhibited in a field near Steele's Tavern, a mile or two from McCormick's home in Rockbridge County, was totally successful. This model, in fact, was merely the first of a long series to be evolved by the inventor himself. Yet McCormick's earliest machine manifested a fusion of the elements which ultimately made effective the instrument of harvesting, notably the placing of motive power, the management of the grain to be cut, the type of the knife, the development and transmission of cutting power and the delivery of the grain after it had been cut. As Professor Hutchinson says, "In spite of the one hundred years of use and experiment since its invention, no alteration which materially changed any one of these parts has been found advisable."

The complete narrative of this contribution to the world's progress would include McCormick's patience in reshaping factors that proved inadequate; his prophetic vision of the future grain empire of America prompting his removal about a decade later to Chicago; his struggle with early competitors; his invasion of Europe, where he won recognition; his competence for developing a business which advertised and then made available the product he had designed; his generosity, turning into forms of helpfulness much of the wealth that rewarded him and making of him one of the chief philanthropists of his generation. His genius triumphed over a stubborn problem of the human environment, and his immense influence upon civilization was entirely beneficent. More than any other, probably, he liberated man from the thraldom of famine's threat; and he established a new sense of security for life.

FRANCIS PENDLETON GAINES,
*President*
WASHINGTON AND LEE UNIVERSITY

## RADIO SYSTEM FOR LANDING AIRCRAFT DURING FOG[1]

### I. Introduction

Tests and demonstrations carried on at the Newark Municipal Airport, Newark, N. J., during March and April, 1933, indicate the complete practicability of the Bureau of Standards radio landing system developed to assist aircraft in making safe landings under conditions of zero visibility. The work on this system was conducted by the Research Division, Aeronautics Branch, Department of Commerce, organized at the Bureau of Standards. The system employs three elements, a runway localizing beacon, marker beacons and a landing beam, to provide continuous and accurate information on the position of the aircraft in three dimensions as it approaches and reaches the instant of landing. Fig. 1 shows the ground transmitting equipment required and the relative location of this equipment on the Newark airport.

[1] Publication approved by the acting director of the Bureau of Standards of the U. S. Department of Commerce.

### II. Runway Localizing Beacon

The runway localizing beacon gives indications of the directional position of the aircraft with respect to the airport and permits keeping the aircraft directed to and over the desired landing runway. A 200-watt transmitting set of the visual-beacon type, operating on 278 kilocycles and feeding small, multi-turn loop transmitting antennas, is employed. At the Newark airport the wind, under conditions of low visibility, is usually from the northeasterly quadrant. The runway beacon, accordingly, is located at the northeast end of the field. With the aid of a goniometer to swing the course anywhere between the two hangar lines, it is possible to accommodate practically all wind conditions during low visibility. On the aircraft, the same receiving set used by air transport operators for the reception of radio range-beacon signals and airways weather broadcasts is employed for receiving the runway beacon signals.

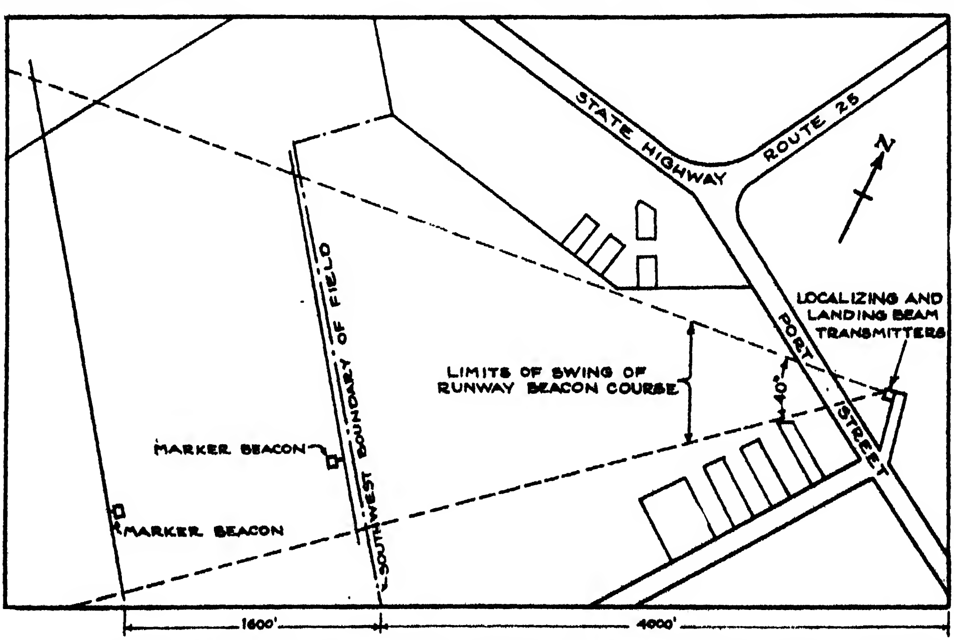



Fig. 1. Location of ground transmitting equipment for radio landing aids at Newark Municipal Airport.

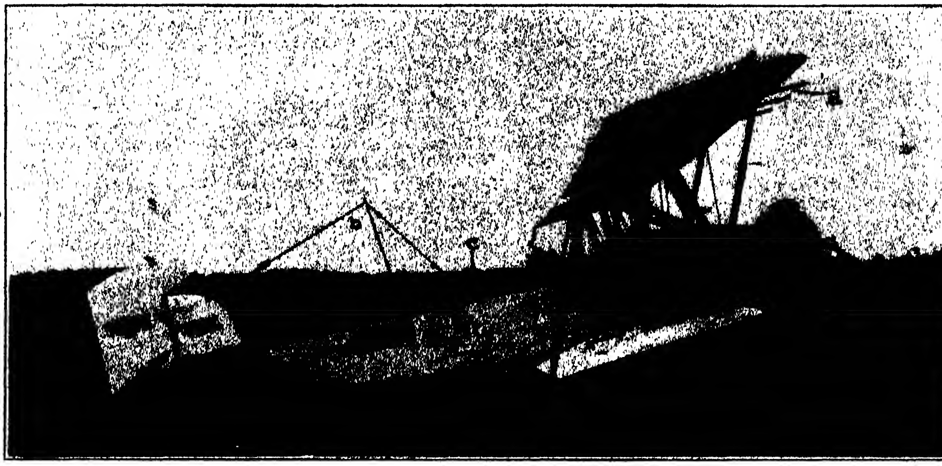


FIG. 2. AIRPLANE USED IN HOODED LANDINGS SHOWING (A) BEACON RECEIVING ANTENNA AND (B) LANDING BEAM RECEIVING ANTENNA.

This set is augmented by a reed converter to convert the beacon signals to pointer-type course indications, given by the vertical pointer of the combined instrument (see Fig. 3), and also by an automatic volume control unit. A vertical index line across the face of the combined instrument represents the desired landing runway, while the position of the pointer corresponds to the relative position of the aircraft with respect to the runway.

### III. Distance Indicator and Marker Beacons

Longitudinal position of the aircraft as it approaches the airport is given by the combination of a distance indicator on the aircraft with the aural signals received from two marker beacons. The distance indicator, operating from the beacon receiver, reads field intensity of the runway beacon and may be calibrated approximately in miles from the beacon (say, 0 to 5 miles). Absolute indication of the longitudinal position of the aircraft when near the airport is given by aural signals from two 5-watt (3,105 kilocycles) marker-beacon transmitters. These signals are received in the output of the high-frequency receiving set normally used for communication purposes. One signal, a high-pitched note, is heard, when within 2,000 feet of the southwest end of the airport. The second signal, a low-pitched note, is received when over the field boundary. The marker beacon transmitting antennas, 2 to 6 feet high, are stretched transversely across the line of flight of the aircraft, to provide signals for all orientations of the runway beacon course.

### IV. Landing Beam

Vertical guidance is given by a horizontally polarized ultra-high-frequency landing beam (90,800 kilocycles). The landing-beam transmitter feeds a directive transmitting antenna array which gives the necessary directivity of beam in the vertical plane while spreading the beam out in the horizontal plane to afford service in the 40-degree sector. On the aircraft, a simple ultra-high-frequency receiver is used, fed by a transmission line from a horizontal half-wave receiving antenna which is located in the wing slightly ahead of the leading edge. (See Fig. 2.) The rectified output from this set operates the horizontal pointer of the combined instrument shown in Fig. 3. The receiver sensitivity is so adjusted that the line of constant received signal below the inclined

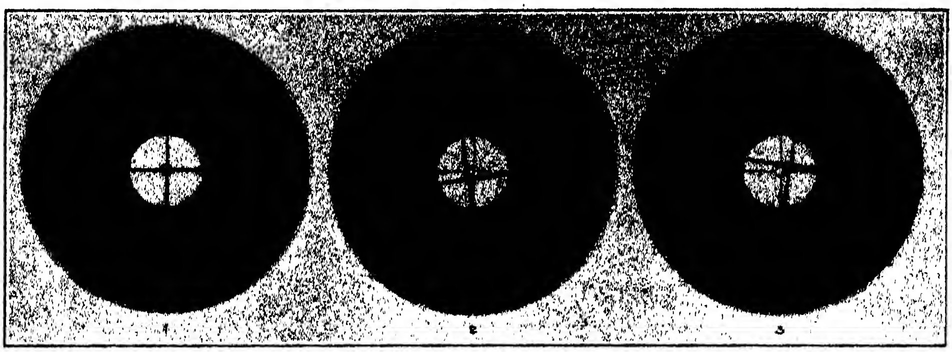


FIG. 3. TYPICAL COURSE INDICATIONS WITH COMBINED INSTRUMENT.

axis of the beam, corresponding to half-scale deflection of the horizontal pointer, marks out a landing path which is suitable for the aircraft and airport considered. The horizontal index line across the face of the combined instrument represents the half-scale deflection and corresponds to the proper landing path. The horizontal pointer represents the position of the aircraft relative to this path.

Referring to Fig. 3, consideration will show that the point of intersection of the two pointers represents the position of the aircraft relative to the desired landing runway and the proper landing path. Three typical course indications are given. Deviations from both courses may be corrected simultaneously. By keeping the pointers crossed over the small circle on the instrument face, a suitable spatial landing path is followed down to the point of landing. The system requires a minimum of manipulation on the part of the pilot. Once the beacon receiver is tuned to the frequency of the runway beacon, no further adjustments of tuning or sensitivity of any of the receiving equipment is required.

## V. Performance Tests

The demonstrations at Newark were preceded by an extensive series of tests at College Park, Maryland, where the practicability of the system was studied by means of flights and landings in an airplane equipped with a canvas hood over the pilot's cockpit. Over a hundred hooded landings were made during these tests. A check pilot was used in the front cockpit to take care of faulty landings or other emergencies. The installation at Newark was then made to determine the operation of the system under the conditions obtaining at a commercial airport. During the two months of tests, besides making a large number of hooded landings, it was possible to fly at all times when the scheduled air mail and passenger airplanes were on the ground because of fog. The operation of the system was demonstrated in the air to many engineers and officials as well as to nearly one hundred air transport pilots.

Perhaps the most striking demonstration consisted of a completely blind flight from College Park, Maryland, to the Newark Airport on March 20. Flying at 3,000 feet altitude, in dense fog, the Washington and New Brunswick radio range-beacons were followed up to the point of tuning in the runway beacon at Newark. The landing beam course was picked up at 3,000 feet altitude at a distance of 7 miles from the airport. Except for an instant over Baltimore, no sight of the ground or sky was had from the time of leaving College Park until receiving the first marker beacon signal at Newark. The aircraft was then only 100 feet above ground.

H. DIAMOND
NATIONAL BUREAU OF STANDARDS

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# THE SCIENTIFIC WORK OF THE BUREAU OF FISHERIES

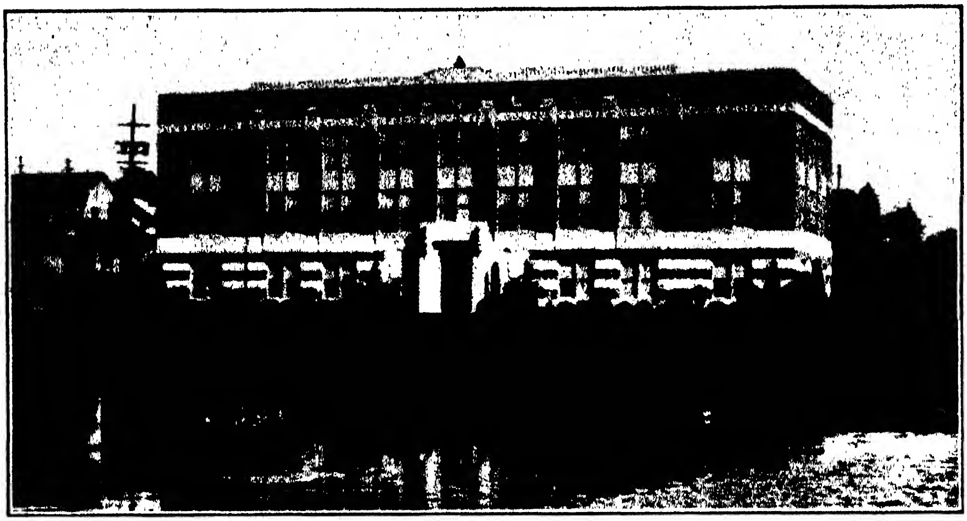
By FRANK T. BELL

COMMISSIONER, U. S. BUREAU OF FISHERIES

THE aquatic life in our coastal waters, in our streams and in our lakes represents a national resource of great but frequently unappreciated value to every citizen of the United States. It supports a poorly organized industry made up in the main of numerous small and scattered units from which about 500,000 of our people gain a livelihood. It produces three and one fourth billion pounds of products that serve as highly nutritious and indispensable food for man and his domestic animals, ranking next to pork and beef as a source of protein, and provides raw materials for a score of industries. In the sea, and to a lesser degree in our interior waters, private ownership of fish does not begin until the catch has been made; fish life is the common heritage of a bounteous nature. Because of the migratory character of most of the important commercial species, which carries them beyond the boundaries of individual states, fishery problems are not only state but also national and international, the last of which is of growing importance. Their welfare is therefore properly the concern of the Federal Government.

The products of the commercial fisheries entering commerce can be gauged by economic standards; the total benefits derived from the fresh-water or sport fisheries are more difficult to evaluate. Some one has made the guess that every game fish is worth a dollar per pound. This may far underestimate the real value, for no one can determine from the huge total spent annually on outdoor recreation what portion is chargeable to the support of angling. Ten million fishing rods were manufactured and sold in 1932. Who can tell how many new automobiles were required to transport the fishermen? Who can estimate the spiritual values of improved health and mental balance induced by fishing?

The functions of the Bureau of Fisheries, the sole federal department concerned with the maintenance and wise use of aquatic resources, therefore, involve the promotion of trade and commerce in the products of the fishing industry, as well as the conservation of a natural resource upon which both industry and public recreation depend. Both of these major functions require the application of scientific principles no less than do the corresponding functions of other government departments which are concerned with the promotion of agriculture, forestry, the development and conservation of mineral resources and the promotion of trade activities. Hence, the Bureau of Fisheries may be classed with the technical and scientific Bureaus of the Government which under a broad interpretation of the police



THE BUREAU'S NEWEST FISHERIES BIOLOGICAL LABORATORY
AT SEATTLE, WASH., IS ADJACENT TO THE CAMPUS OF THE STATE UNIVERSITY. IT PROVIDES LABORATORY QUARTERS FOR THE BIOLOGISTS OF THE BUREAU ENGAGED IN STUDIES OF THE ALASKA FISHERIES AND THE MARINE FISHERIES OF THE PACIFIC COAST STATES, AS WELL AS THE STAFF OF THE INTERNATIONAL FISHERIES COMMISSION OF THE UNITED STATES AND CANADA ENGAGED IN INVESTIGATIONS AND CONTROL OF THE HALIBUT FISHERY OF THE NORTH PACIFIC.

powers of the state assure to all our citizens equal opportunity in the fullest enjoyment of inherited rights in their common property.

To appreciate the relations of the purely scientific functions of this Bureau to its administrative activities, a word may be said about the organization itself.

### ORGANIZATION

The Bureau of Fisheries owed its inception to the widely entertained opinion that the fisheries in general were diminishing in value and importance on account of the intensity and methods with which they were prosecuted. The American Fish Culturists' Association (now the American Fisheries Society) took a leading part in advocating an investigation of the subject, and largely through its influence and the representations of state fishery officers Congress passed a joint resolution, approved February 9, 1871, which provided for the appointment of a Commissioner of Fish and Fisheries, who was directed to conduct investigations concerning the facts and the causes of the alleged diminution and the feasibility of remedial measures. This was the beginning of one of the earliest and most effective conservation movements undertaken by the Federal Government.

Until July 1, 1903, the establishment was independent, reporting directly to Congress, and was known as the United States Commission of Fish and Fisheries, but on the organization of the Department of Commerce it was included by law in the new department and the name was changed to its present designation.

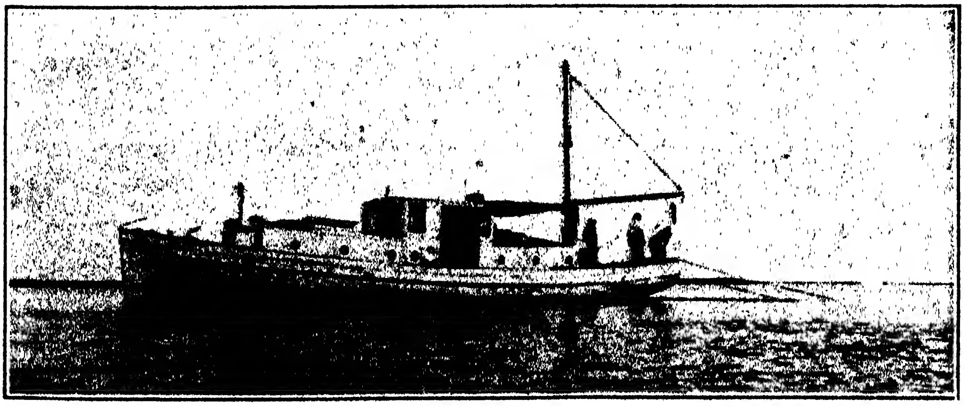
As now constituted the Bureau is concerned with the wise husbandry of our fishery resources. This includes the collection of biological and statistical data to reveal the condition and trend of the important fisheries; the development of the science of aquiculture as a means for improving fish cultural practises, and developing water farming on a commercial basis; the propagation and distribu-

tion of food and game fishes to replenish the natural supply; and the conduct of economic and technological studies to assure the wise use of the fishery harvests.

Acting in an advisory capacity, the Bureau has been able to exert a powerful influence on the fisheries legislation of the states. Local authorities and interests hold its work in high regard, and, appreciating that its advice is authoritative and disinterested, frequently seek it. Members of its staff are called on to serve with and assist state commissions and frequently to address state legislative bodies on topics connected with the administration of the fisheries and to assist in the drafting of state fisheries laws. It is also represented on commissions having to do with international fisheries questions of conserving the supply of aquatic animal life—fishes and mammals.

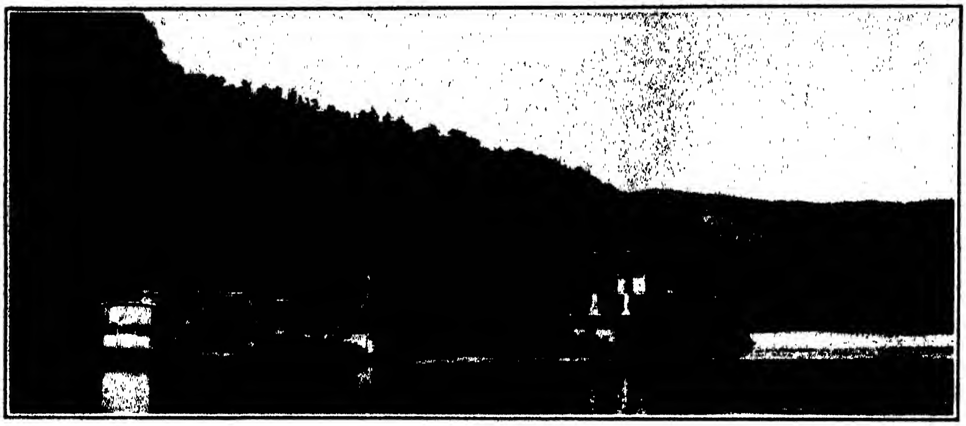
Formerly the Bureau was wholly without administrative or executive control of the fisheries, as these functions are vested in the several states within whose territorial limits the fisheries are located. By an order of the Secretary of Commerce, dated February 15, 1905, the Bureau for the first time was charged with the administration of the salmon fisheries of Alaska. Subsequently by law this jurisdiction was extended to all the fisheries of Alaska. On December 28, 1908, the Alaska fur-seal service, which since the formation of the Department had been administered through the Secretary's Office, was transferred to the Bureau. By act of Congress in 1906 the Department became charged with the duty, which is also exercised through the Bureau, of controlling in certain respects the sponge fishery prosecuted on the high seas off the coast of Florida.

The Bureau has a staff of 78 persons attached to the central office at Washington and a field service of 466, not including temporary per diem employees. Its work is organized under five divisions, the Division of Administration, the Division of Fish Culture, the Division of Inquiry Respecting Food Fishes ("Scientific Inquiry"), the Division of Fishery Industries, and the Division of Alaska Fisheries, which latter is divided into the fur-seal service and the fishery service. Two of these divisions are directly engaged in scientific investiga-



THE BUREAU'S RESEARCH VESSEL "BLACK MALLARD"

IS OPERATED BY THE LOUISIANA DEPARTMENT OF CONSERVATION FOR THE PURPOSE OF COMBINING SCIENTIFIC STAFFS OF THE TWO ORGANIZATIONS IN A COOPERATIVE INVESTIGATION OF THE LIFE HISTORY, HABITS AND CONSERVATION REQUIREMENTS OF THE SHRIMP OF THE SOUTH ATLANTIC AND GULF COASTS. HERE EXPERIMENTAL HAULS WITH A COMMERCIAL SIZE SHRIMP TRAWL ARE BEING MADE IN BARATARIA BAY, LA., TO PROVIDE DATA REGARDING THE SHRIMP POPULATION OF THAT IMPORTANT FISHING GROUND.



THE BUREAU'S FLOATING LABORATORY IN THE MISSISSIPPI VALLEY
QUARTERBOAT 348 IS HERE BEING MOVED UP THE TENNESSEE RIVER BY THE ARMY ENGINEERS' STEAMER FOR A THOROUGH LIMNOLOGICAL SURVEY, WHICH WILL FORM THE BASIS OF RATIONAL CONTROL AND DEVELOPMENT OF AQUATIC LIFE IN CONNECTION WITH PENDING REFORESTATION, FLOOD CONTROL AND HYDROELECTRIC DEVELOPMENT PROJECTS IN THAT GREAT RIVER VALLEY.

tions. Studies of a more strictly biological nature concerned chiefly with problems of the supply of the food and game fishes and its maintenance in a state of highest productivity are handled by the Division of Scientific Inquiry, while those of a technological or economic nature concerned with the proper utilization of fishery products and the dissemination of trade information are conducted by the Division of Fishery Industries.

Scientific investigations are prosecuted at a large number of permanent and temporary field stations. In addition to the laboratories in the Department of Commerce Building in Washington, four permanent fisheries biological laboratories are operated, two on the Atlantic Coast, at Woods Hole, Massachusetts, and Beaufort, North Carolina, respectively; one in the Mississippi Valley at Fairport, Iowa, and one at Seattle, Washington.

Field stations are operated cooperatively with the states at Milford, Connecticut, Brunswick, Georgia, New Orleans, Louisiana, and Olympia, Washington. The Bureau owns two experimental fish cultural stations, one at Pittsford, Vermont, and one at Leetown, West Virginia, and cooperates with the State of New York and Cornell University in the operation of the experimental hatchery at Cortland, New York.

Field headquarters are also maintained at various universities throughout the country where excellent laboratory and library facilities are furnished. These universities include Harvard, Yale, University of Michigan, University of Missouri, University of Utah and Stanford University. In addition to the well-equipped fishery products laboratory in Washington, temporary technological laboratories are established at important fishing ports in accordance with local needs, the largest of which has been operating for more than two years at Gloucester, Massachusetts.

Until the beginning of the present fiscal year, the Bureau has operated a number of vessels, launches and floating laboratories in the conduct of its scientific investigations. Various phases of the North Atlantic fishery investigations have required the full time of the *Albatross II*, a 150-foot steam vessel, equipped for oceanographic work and experimental trawling. Fishery studies

in Lake Michigan have been prosecuted from the motor ship *Fulmar,* a 102-foot vessel, equipped for experimental fishing and limnological study. On the Mississippi River two houseboats and various launches provide laboratory and collecting facilities; one, an 85-foot quarterboat, has a large and well-equipped physiological and chemical laboratory and accommodations for a dozen workers. In Alaska a 45-foot launch is used exclusively for herring investigations and various others of the Bureau's large fleet of vessels are employed as circumstances warrant.

### Biological Investigations

The major scientific projects of the Division of Inquiry are included in three fields: marine and fresh-water commercial fishery investigations, investigations pertaining to game fishes and shell-fishery investigations. The study of the marine and fresh-water commercial fisheries is properly classified and is now generally recognized as a distinct branch of science variously known as fishery biology or fishery science. The problems encountered in the promotion of shellfish culture and the growing of food and game fish for stocking interior waters are included in the rapidly expanding field of aquiculture.

Doubtless the most significant and fundamental problems affecting the supply of raw materials to the commercial fisheries are overfishing, fluctuations in abundance and management of the supply. Although many people still believe implicitly in the inexhaustibility of the resources of the sea, in which views they are upheld by contemplation of the vast areas of waters, the tremendous fecundity of aquatic animals and the antiquity of the great sea fisheries, the fear of depletion of the more valuable species by commercial fishing has been the foundation of all governmental activity in connection with fishery investigations. That these fears were not ill-founded is amply proved by experience and, in a few cases, by sound scientific investigation. We need only look back over the statistical records of such fisheries as the Atlantic salmon and halibut, the shad and alewife in the coastal rivers of the Middle Atlantic States and in New England, and the sturgeon in these rivers and in the Great Lakes to be convinced that disaster can overtake such fisheries as the inevitable result of intensive or destructive fishing, which, in some cases, is coupled with the pollution of waters or the obstruction of spawning beds.

It is true that coastal and anadromous fishes, being within easy reach of the fishermen's nets or, because of their peculiar life history, actually assembling in mass and coming to the fisherman's very door to be caught, are more vulnerable than the pelagic forms, but even deep sea fisheries are subject to serious reduction as is evidenced by the fate of the Pacific halibut and by the history of the plaice fisheries of the North Sea.

Depletion in the commercial fishery is usually understood as a decline in yield per unit of effort, but a reduced level of supply in any species may be the result of a vast complex of natural causes and not solely the result of overfishing for great variations in abundance have been observed in nature which are in no way related to depletion. Overfishing, therefore, may not be judged alone by an absolute decline in the numerical strength of the fish population in any area, for biological criteria of depletion exist that must be taken into account.

One of the major objectives of the Bureau's biological investigations is to discover the earliest signs of depletion of the supplies of commercial species before total landings have declined to such an extent that commercial fishing operations are no longer profitable and before depletion has become so extensive that the very existence of valuable food supplies is threatened. The security of

AT THE FISHERIES BIOLOGICAL STATION, FAIRPORT, IOWA

STUDIES ON INCREASING THE PRODUCTION OF WATER AREAS THROUGH FERTILIZATION TO INCREASE PLANKTON GROWTH HAVE RESULTED IN PRACTICAL IMPROVEMENTS IN BASS CULTURAL METHODS. THIS HAS INCREASED THE YIELD OF THE EXPERIMENTAL PONDS FROM 5,000 BASS PER ACRE, WHICH A FEW YEARS AGO WAS CONSIDERED SATISFACTORY, TO MORE THAN 20,000 PER ACRE. HERE THE CREW IS REMOVING THE BASS FROM AN EXPERIMENTAL POND AT THE END OF THE GROWING SEASON. THE MAIN LABORATORY IS SEEN IN THE BACKGROUND.

large investments in gear, vessels, factory equipment and the entire machinery of preparation and distribution, as well as the livelihood of thousands of people directly or indirectly dependent upon the fishing industry for support, can only be assured by continued vigilance on the part of the responsible governmental agencies entrusted with the conservation of national wealth and well-being.

The expression "fisherman's luck" summarizes the fact that the yield of the fisheries both locally and over wide areas is extremely erratic and a great mass of scientific evidence now available indicates that these changes in yield are primarily caused by major fluctuations in the actual abundance of the various fish stocks. Such variations in abundance are also found in land animals, and attempts have been made to discover cyclic changes related to world-wide factors such as solar variations and the like.

The study of these fluctuations in abundance forms the major activities of the biologists of the Bureau of Fisheries in the North Atlantic area and is being applied to the haddock, mackerel, scup and weakfish. There can be no doubt that this general principle applies to the supply of all fishes, but probably the most spectacular variations are found in the mackerel fishery which has been studied for several years.

From a study of the age-composition of the commercial catch of mackerel, together with the records of landings, data have been secured which indicate that some year-classes are produced in great abundance. On the basis of these studies in which the relative strength of the various year-classes is calculated, together with their rates of decline, predictions of the expected yield have been offered for several years. These predictions have great potential value to the fishing industry. If a season of unusual abundance may be foreseen, marketing channels may be prepared for expanding distribution, and the technological proc-

esses, such as freezing, salting, canning and packing, may be planned to take care of the excess production, thus preventing glutted and demoralized markets, which too often drive prices so low as to cause real distress among the fishermen. Conversely, in seasons when scarcity appears inevitable, the cost of such preparations can be saved and accumulated stores of processed fish may be released to supplement current production. Predictions have, therefore, been released, first made public in fishing and trade journals and later by Bureau publications.

Although no reports have been published, similar predictions have been prepared for several years for the major runs of salmon in the important fishing districts of Alaska. Strangely enough these predictions are based on less precise data than are available for the pelagic sea fisheries. They include such factors as the known escapement of spawning salmon and their age-composition, the physical conditions upon the spawning beds, the estimated production of young salmon migrating seaward, the normal age at maturity and various other indications such as, for example, in the red salmon, the number of grilse or precocious males returning in the year previous to the year of prediction and which are believed to bear a fairly definite relation to the number of normally maturing adults. These predictions are becoming increasingly accurate and already have provided such valuable information for the salmon canning industry that they are accepted as an important basis for the regulation of the fisheries by the Government and for the commercial preparations for packing activities the ensuing year. There is no doubt that additional research along these lines will bring still closer the practical control of fishing operations and the maintenance of the stock of fish.

From the investigations of the haddock fisheries off the New England coast it is becoming increasingly evident that success or failure of the great trawl fishery, employing nearly 100 of the largest vessels in the fishing fleet, depends upon success or failure of spawning and survival of the young and not directly upon the numbers of spawning adult haddock. The decline of the haddock fishery from its maximum in 1929 to a minimum in 1932 is thus attributed to failure of reproduction in the years from 1926–28. Improvement in the yield is anticipated because of the relatively successful spawning year of 1929 which produced more young haddock than any year since 1924.

For the first time the mystery which has shrouded the life history and habits of the shrimp on the South Atlantic and Gulf Coasts is yielding to scientific research. Although the investigation started as recently as 1931, the extreme vulnerability of the shrimp supply to overfishing has been demonstrated. Because of the fact discovered during the year that the important commercial species have a life cycle limited to about one year, warning has been issued to the states that the fisheries should be diligently observed for first signs of depletion, which when it appears will almost certainly run a tragically rapid course resulting in disaster for this extensive industry. The major features of the life history of the shrimp have been sketched as a basis for wise conservation measures when they are needed.

Investigations of the important commercial fisheries of the Great Lakes during the past year have been concerned almost wholly with the abundance and distribution of the various species of food fishes and the effects upon the fish populations of the various types of commercial fishing gear. Although the yield of the commercial fisheries in these waters has been maintained in the aggregate for several decades, it is gen-

ON THE SHORES OF LITTLE LAKE

A TRIBUTARY OF BARATARIA BAY, LA., 30 MILES FROM THE GULF, THE BUREAU'S INVESTIGATORS HAVE DISCOVERED AN IMPORTANT NURSERY GROUND FOR MINUTE YOUNG OF THE IMPORTANT COMMERCIAL SPECIES OF SHRIMP. BY SUCH PERSISTENT EFFORTS THE LIFE HISTORY OF PENAEUS HAS BEEN TRACED FROM ITS SPAWNING IN THE GULF OF MEXICO, ITS MIGRATION INTO FRESH WATER AND ITS RETURN TO THE GULF FOR SPAWNING AND DEATH A YEAR LATER.

erally known and recognized that depletion of the important species is occurring with greater rapidity in some lakes than in others, and that total production has been maintained by the substitution of less valuable species for the ones that are more valuable and better known. The efforts of the Bureau's technical staff at present are directed toward the correction of abuses in the commercial fishery and especially the reduction of the tremendous wastage of immature and undersized fish that annually reaches impressive proportions.

During the past few years the Bureau's investigations in aquiculture have been successful in improving hatchery technique, combatting disease which annually takes heavy toll of trout and other game fishes crowded under unnatural conditions in hatchery troughs, and in improving strains of brood fish that are more productive and more disease-resistant than wild stock. Improvements are constantly being made in developing diets that will produce growth, vigor and color in hatchery-reared fish equal or superior to those found in nature. At the same time material economies in operation have been effected by the use of cheaper food materials.

Improvements in the restocking of inland waters are resulting from the Bureau's program of stream survey. The extension of highway travel and the rapid increase in the number of anglers have necessitated radical changes in the methods of planting and have demonstrated the necessity for systematic stocking based upon accurate knowledge of conditions of fish life existing in the more accessible lakes and streams. Since the Bureau's responsibility for maintaining and improving angling is definitely indicated in the waters of the public domain, limnological investigations have been concentrated in the national parks and forests in the intermountain region and will be extended to other areas as funds and personnel permit. Studies already made under this program are yielding results in systematic stocking of public waters that will be increas-

THE SALMON WEIR AT ANAN CREEK IN SOUTHEASTERN ALASKA

IS TYPICAL OF A CONSIDERABLE NUMBER OF SUCH STRUCTURES PLACED IN THE MORE IMPORTANT SALMON STREAMS OF ALASKA FOR THE PURPOSE OF COUNTING THE NUMBER OF SPAWNING FISH THAT ASCEND THE RIVERS. ENUMERATORS STATIONED AT THE GATES IN THE WEIR TALLY EACH FISH OF THE VARIOUS SPECIES COMPRISING THE SPAWNING RUNS, WHICH UNDER THE WHITE ACT OF 1924 MUST EQUAL THE NUMBER OF FISH TAKEN BY THE COMMERCIAL FISHERIES AT THE MOUTHS OF THE RIVERS. IN ADDITION TO THE IMMEDIATE PRACTICAL CONTROL OF FISHING OPERATIONS THE DATA THUS OBTAINED HAVE GREAT SCIENTIFIC VALUE.

ingly apparent to the angler from year to year.

Investigations concerning various problems of the oyster industry were carried out in New England and the North Atlantic states, South Atlantic states and on the Pacific coast in Washington and California. The selection of specific projects of study in different sections of the country was governed both by the local conditions and most urgent needs of the industry. Thus, in New England and the North Atlantic states, where previous work of the Bureau materially helped in the solution of the problem of propagation of the oyster, the main efforts were directed to a study of the methods of growing, fattening and improving the nutritive quality of oysters. On the other hand, in the South Atlantic states where the depleted condition of the natural oyster reefs threatens the existence of the industry, principal attention was given to the methods of restocking and maintaining the productivity of the bottoms. On the Pacific coast the work consisted in studies of the cultivation and development of the native Olympia oyster.

Because of their close association, the Bureau has investigated simultaneously problems concerned with the propagation and conservation of the fresh-water pearly mussels of the Mississippi Drainage and pollution of these waters by industrial and sanitary wastes and silt. Despite closed seasons and various restrictions on the mussel fishery, the supply has declined seriously in recent years and efforts at restocking have failed because of the tremendous increase in the load of silt carried by the rivers, which in turn render the increasing volume of municipal wastes more and more destructive of life in polluted waters. From careful limnological surveys of the greater portion of the principal streams in the Mississippi Drainage it has been found that the uncontrolled introduction of silt into

these streams has increased tremendously the areas disturbed by the major pollution centers of the great cities.

Since such silt makes it impossible for the streams to rid themselves of the huge volume of organic wastes now being poured into these waters, the pollution problem has become so serious that aquatic life has been practically reduced to those few undesirable forms capable of surviving in highly polluted waters. The combined pollution is spreading with amazing rapidity, menacing alike the mussel resources and the food and game fishes.

### Technological Investigations

Never before in the history of the fishery industry of this country has there been greater need for economy in production methods and for the fullest utilization of valuable products from the material at hand. Losses or leakages in factory operation, which in more prosperous times seemed relatively unimportant, now represent very frequently the margin between profit and loss. Never before was there greater need for the application of the best technological and engineering knowledge available to problems of manufacture, preservation and marketing of marine products than at present. This is absolutely essential to make the most of the raw material available, to eliminate waste, and to bring factory operation to the highest point of efficiency. With this objective in mind, the technological research of the Bureau has followed the general lines of studies of methods of manufacture, preservation, storage and marketing of both the primary products of the fisheries for food and the by-products for animal nutrition, biochemical tests to determine the food value of marine products, the development of fishing gear, and experiments in developing chemical treatments of fishing nets to lengthen their useful life. This has involved the application of the sciences of chemistry, engineering, bacteriology and general technology to the solution of these problems.

One of the most productive lines of investigation undertaken recently by the Bureau is the analysis of the nutritive value of marine products. Fish oils are generally recognized as a valuable source

THE SHALLOW BAYS OF CONNECTICUT AND RHODE ISLAND

ARE THE MOST IMPORTANT PRODUCTION CENTERS FOR SEED OYSTERS, SUPPORTING THE GREAT OYSTER FARMS OF LONG ISLAND SOUND, ALTHOUGH RELATIVELY FEW YEARS IN A DECADE PRODUCE GOOD CROPS. THE BUREAU'S CREW IS HERE PLACING ARTIFICIAL COLLECTORS TO CATCH OYSTER SPAT TO DETERMINE THE BEST MEANS OF INCREASING PRODUCTION.

of vitamins important in the diet, and the supply has been obtained chiefly from the liver oils of the cod and cod-like fishes. Recent investigations, however, have demonstrated that other species contain in some cases greater quantities of vitamins A and D than cod-liver oil. One of these is halibut liver oil which is at least 50 times richer in vitamin A than medicinal cod-liver oil. Salmon liver oil has been shown during the past year to be 10 to 12 times as potent in vitamin A. However, difficulties in extraction of this oil have prevented its general use, and study is being given to this question. The discovery of high vitamin potency in sardine oil has tremendously expanded the market for this domestic product in poultry feeding at a great economic gain to our producers and farmers.

It has also been known for many years that shell-fish properly prepared were likewise richly supplied with various vitamins important in a balanced diet. Sound investigations by the Bureau's staff in cooperation with other food research agencies demonstrate that oysters, because of their unusually high content of copper and iron in organic combination, are particularly valuable for combatting nutritional anemia. Oysters from different localities on the Atlantic and Gulf Coasts, while differing in their iron and copper contents, were fed to anemic animals and all induced marked regeneration of hemoglobin, thus giving further evidence of the importance of oysters as a source of iron in addition to their other food factors.

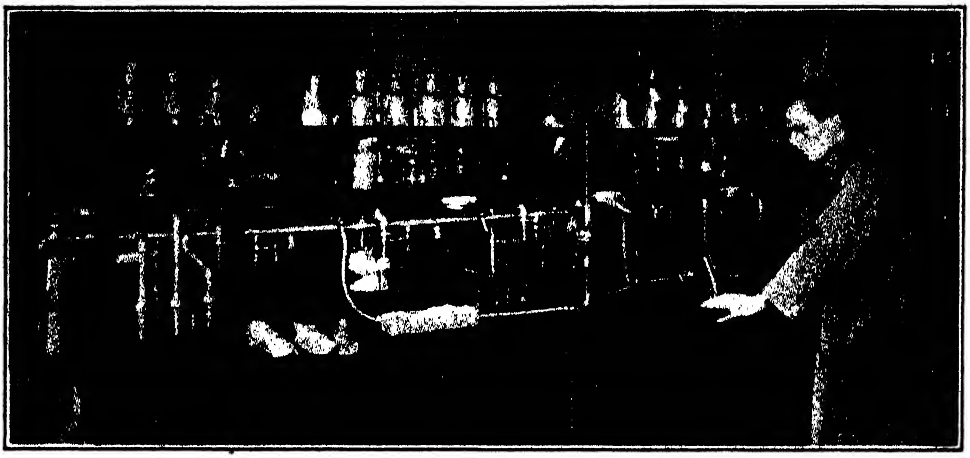
Technological and engineering studies have also been undertaken upon problems of properly preserving and handling fishery products and by-products in order to assure their highest quality at the time of delivery to the consumer. Such studies have been made as to the determination of proper storage temperature for frozen fish that will permit the least evaporation and that will retard the action of enzymes that result in gradual spoilage of the product. The technique of freezing and storing of several species of shell-fish has been given consideration including the proper temperature of freezing, the most efficient temperature for storage, the effects of defrosting, and the rate of spoilage after defrosting. Improved methods have been devised for smoking fish in which proper temperature, humidity and the composition of the preserving agent have been found to be important.

CARDBOARD MATS LIKE EGG CRATE PARTITIONS

COATED WITH A THIN LAYER OF CEMENT, HAVE BEEN DEVELOPED BY THE BUREAU AS A MOST EFFECTIVE OYSTER SPAT COLLECTOR. THIS COLLECTOR EXPOSED ON THE FLATS IN MILFORD HARBOR, CONN., OBTAINS 100 TIMES MORE YOUNG OYSTERS THAN COULD BE COLLECTED BY THE OYSTER SHELL CULCH USUALLY EMPLOYED. THE COLLECTOR WILL BE CRUSHED AND THE PIECES PLANTED IN DEEP WATER WHERE FINE SINGLE OYSTERS WILL DEVELOP WITHOUT CROWDING.

Bacteriological studies on processes of preservation have been undertaken. As a result of these studies objective tests for the freshness of fishery products have been devised which correlate chemical reactions with bacterial counts of the flesh and which give promise of having wide application to the fishing industry.

In most industries the income from the marketing of the major products pays only for the expense of operation and production; profit is frequently de-



THE TECHNOLOGICAL LABORATORIES OF THE BUREAU OF FISHERIES IN THE NEW COMMERCE BUILDING AT WASHINGTON, D. C., ARE WELL EQUIPPED FOR CHEMICAL ANALYSES, PHYSICAL DETERMINATIONS AND TECHNOLOGICAL EXPERIMENTS IN THE HANDLING OF FISHERY PRODUCTS. THE NUTRITION LABORATORY ALSO MAINTAINS A RAT COLONY OF STANDARD STOCK FOR BIOLOGICAL ASSAYING OF THE VITAMIN AND NUTRITIONAL VALUES OF FISH MEALS, OILS AND OTHER PRODUCTS OF THE MARINE FISHERIES.

rived primarily from the marketing of the by-products. Because of antiquated methods and the decentralization of supplies, possibilities in this direction have never been realized by the fishing industry. Considerable attention has been given, therefore, by the Bureau's staff to the by-products industry in the fisheries, and extensive studies of an engineering and technological nature have been conducted on perfecting methods for manufacturing fish meal from the non-oily fish wastes and meal and oil from menhaden and other oily fishes.

Conversion of wastes derived from the preparation of packaged fishery products has an important bearing on the fishing and agricultural industries. The conversion into a useful product, fish meal, brings added revenue to the fishing industry, and to agriculture one of the most highly nutritive protein concentrates obtainable. As a service to these industries, it is important that the fundamental factors of manufacture, as related to the preservation of nutritional values, be understood fully, and further it is of primary importance to obtain information as to the most economical means of obtaining this end. Biological tests of the products have demonstrated that the digestibility, vitamin value and general nutritive value are affected by drying, by temperature of drying and the method of applying heat. The details of the most effective means of preparation will be released for industrial use.

Various other studies of an engineering nature have been conducted; one of importance concerns improved methods of preserving net materials. The deterioration of cotton webbing used in fish nets entails a heavy financial loss to the fishing industry annually, which can be largely reduced by chemical treatment of the fabric which prevents bacterial invasion, oxidation of the fiber and the fouling by marine growths.

### Statistics of the Fisheries

If wise conservation measures are to be enacted to perpetuate the fish population, if the element of "luck" in making the catch is to be removed, and if the fishing industry is to be supplied with

trade and market or distribution statistics, it is necessary that figures be collected on various activities of the fishing industry. These should show not only the yield of the fisheries according to species and locality and the manufactured products, but if sufficiently extensive should provide a fairly accurate index of relative abundance of fish in the sea. This is the aim of the statistical investigations of the Bureau of Fisheries.

In former years the various geographic sections of the country were canvassed by enumerators at irregular intervals. Recently, however, it has been possible to obtain for each year a comprehensive record of the total quantities of fish landed during the previous year so that annual statistics of the aggregate yield of the fishery are now available.

Four main types of statistical surveys are conducted by the Bureau. These are (1) the general canvasses, (2) canvasses of landings at certain important fishing ports, (3) canvasses of special fisheries, and (4) canvasses of the industries marketing or manufacturing fishery products. In the general canvasses figures are obtained on the catch of the various species and their value as landed by the fishermen, the quantity or number of each kind of gear used, the locality of capture, and the number of fishermen employed, the number of fishing boats and the net tonnage of fishing and transporting vessels. Statistics are collected also on the activity of plants, manufacturing and marketing products, including annual catch, the number of wholesale establishments and other economic data regarding wages, number of employees, and products canned, smoked, salted, packaged or frozen. These figures are tabulated at the Bureau and are issued monthly or at short intervals in order to provide prompt information to the industry.

Recently Dr. Julius Klein, former Assistant Secretary of Commerce, stated, "Future existence will be connected more and more with conceptions based on statistical information." To form a basis for conceptions of the fishing industry as a guide to commerce, the Bureau is endeavoring to supply adequate statistical data on the potential supply, the production and the distribution of fishery products.

# THE MAYA AND MODERN CIVILIZATION[1]

By Dr. ROBERT REDFIELD
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THE name "Maya" is so generally associated with ancient ruins and the mystery of a departed people that, before setting forth certain research plans of Carnegie Institution of Washington, it should perhaps be stated that the Mayas are not extinct. In fact, Maya Indians still constitute the largest element in the population of present-day Yucatan. The blood of the race that built the old cities predominates in the persons of several hundreds of thousands of men and women now alive. The Maya language, probably not very different from that spoken by the Indians who built Coba and Uxmal, is still the general language of communication outside of Merida, the capital of the present Mexican state of Yucatan. In fact, speeches in that language on such subjects as socialism, or the reasons for the economic depression, are delivered almost every day.

But these Mayas are not a vestige of a disappearing primitive tribe, melting away with the coming of civilization, like some of the Oceanic peoples. They are racially intermixed with Spanish whites; and they are not destined to extinction, but are to become one part of modern world civilization. And the process of so becoming involves a number of scientific problems for the student and of practical problems for themselves. As communications develop, as roads are built, schools multiply, moving-picture theaters are introduced and newspapers are read, the primitive and illiterate Indians of the hinterland undergo great social changes; and cor-

[1] Some of the illustrating photographs were taken by Alfonso Villa and some by the author.

THE SCHOOL AT CHAN KOM

responding changes take place among the whites and mixed bloods of the city.

These are the problems that interest us in carrying on work in social anthropology in Yucatan.[2] What ought to be done about the practical problems is not our immediate concern, but if anything can be found out as to how changes of this sort take place, such knowledge can by others be made of practical use. Some of us regard it as the function of scientific activity to enable people better to understand and to deal with the world around them. Society thinks this way about it too, I believe, for although individual scientists often (and rightly) carry on their work for its own sake, yet society supports science in the hope and belief that its activities may help men to get about in the increasingly intricate paths of living. It is natural that of those who have the ultimate serviceability of science in mind, some should choose to submit men's own ways to scientific observation and description, the better to understand their nature, their characteristic forms and manifestations. Human activities are the most immediate and important of natural phenomena.

Ethnological work among the Indians is often done because the student wants to find out what those Indians were like before the white man came, and how Indian civilization arose and developed in aboriginal America. This is also what the archeologist is engaged in investigating, and it is certainly a fascinating inquiry. Such historical studies add to the content of our knowledge; when they give us insight into how life looked to these ancient people, to an extent we have through them experiences never actually ours. Such knowledge of other people's lives is like an education in the humanities. In studying the customs of present-day peoples, the knowledge one gets is much the same sort. But some students wish to reduce this knowledge to types, to treat cultural behavior as a natural phenomenon with its characteristic and recurrent attributes. There is in such students the desire to know how customs and institutions arise, take form and change form.

It may be said that historical accounts of Maya culture origins throw light on this question, but to this it may be replied that the archeological account of culture changes is often lacking in detail. Sometimes it is no more than a statement as to tribal migrations, and as to cities founded and abandoned. In the details of social change, the precise circumstances under which men come to alter their ways, the little events that initiate changes—in respect to these the archeological record is necessarily deficient. At any rate, the flow of life is better observed in all its richness when it is flowing; recovery of the flow by historical inquiries after it has passed yields a less full and intimate body of materials. Thus, though the social anthropologist joins hands with the archeologist in a common interest in the Maya, and eagerly appropriates what he can tell of the events that led up to their present social organization, he must derive most of his materials from direct observation of contemporary culture in its eternal making and re-making.

This kind of observation may be made, one properly suggests, anywhere that social changes are going on, without the necessity of a trip to Yucatan. This is true, but there are certain reasons for welcoming the opportunity, given by Carnegie Institution, to express this interest in the Maya field. There are more immediate reasons arising from the facilities afforded by the institution, and from the presence in the Yucatan peninsula of scientific workers

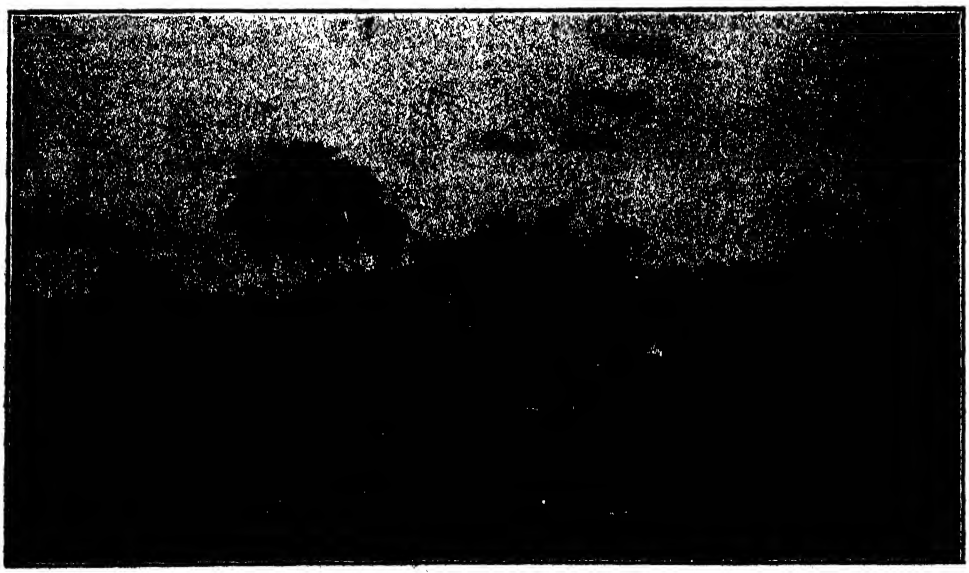
[2] The project outlined in these pages is promoted by Carnegie Institution of Washington; by an arrangement with the University of Chicago, the writer is enabled to devote part of his time to it.

of different yet related interests. There are also reasons arising from the nature and distribution of culture and civilization in Yucatan.

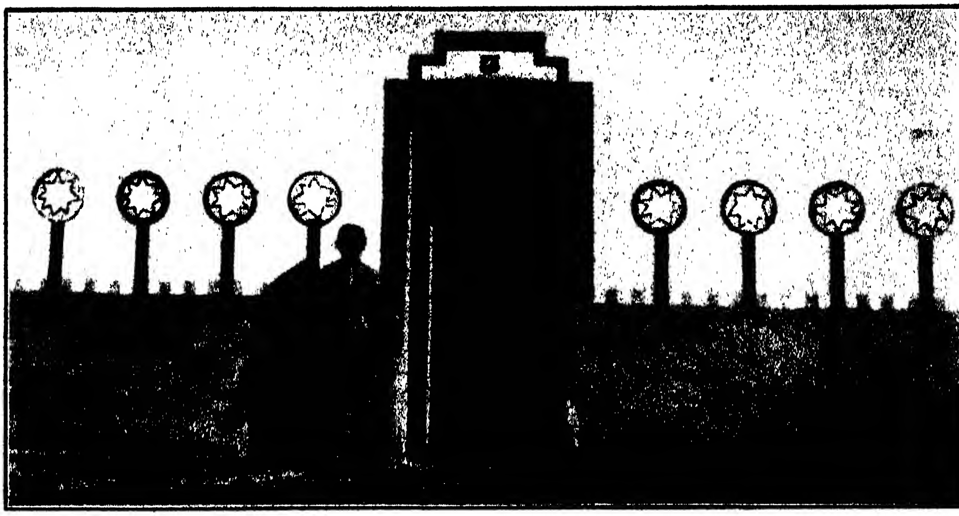
That peninsula, virtually an island by reason of the natural barrier to communication formed by the tropical forests of the south, contains within it a short outline of civilization. For its inhabitants represent the range of social development from the primitive tribe to the modern city. There are Indians in the south who use the bow and arrow and follow entirely pagan and aboriginal religions, there are city dwellers in the capital who do business in the credits of international finance and whose interests are cosmopolitan, and there is every intermediate degree of sophistication.

Nor are these various cultures static: they are all changing under the influences of that expanding system of industrial civilization which we call "Western," but which is no longer confined to any one quarter of the earth. South African hemp fibers compete with the sisal of Yucatan, and the price of labor in Africa is a matter of importance to the Maya Indians. Other Maya, in the less accessible forests of Quintana Roo, have changed their mode of living in response to the demand for chewing gum fomented by modern advertising in cities of which they have never heard, but of which, as another result yet to come, they will one day hear.

The great spread of trade, machines and communications effects the important changes of to-day, that in our own country and in western Europe take the form of the expansion of the metropolitan area and its zone of influence, and that in the wider world bring about the breakdown or reorganization of the primitive and the "medieval" societies. The widening circles of industrial civilization reach all the "backward peoples" and bring them a leaven of unrest. Of changes of this latter sort those going on in Yucatan are an instance; the country is relatively near our own, and we have been given the opportunity to observe and report on these changes as they are taking place.



THE OLD STYLE MAYA HOUSE



THE NEW STYLE HOUSE—CHAN KOM

One stands a good chance of improving the methods for making such studies anywhere, in the attempt to make one such study in Yucatan. At any rate, in so defining our problem we may hope to do a little more than collect information on the customs of the Maya Indians. Advance in science is marked not so much by how much more you know as by what new and better ways you have for knowing.

The plan of study in Yucatan, entirely tentative and experimental, is the simultaneous study by similar methods of sample communities along the range of civilization that exists in Yucatan. We can not study every community, but we can select those that we do study so that they represent stages in this course of change: we can study an isolated and primitive bush village, another village of people with a similar cultural heritage but who have had schooling and opportunity to communicate with the towns, a third community (near the city) of wage earners who go to the city and to the movies; and we can make studies in the capital city itself. Such studies, if carried on in the same terms, should yield a comparison that would roughly represent the process of civilization, or urbanization. At least it should suggest some of the ways in which the stable societies of non-literate people, dependent on a local tradition, give way to the more mobile and individuated society of the modern city.

In furthering this plan we have done some preliminary work in the city of Merida, and we have entered upon a study of one community, a village named Chan Kom, situated in the southeastern part of the state of Yucatan not far from the archeological site of Chichen Itza.

Chan Kom is a place about in the middle of the scale of civilization in Yucatan: there are other communities less civilized and others more so. It lies on the outer margins of the area controlled by the state government and affected by roads and schools. Its two hundred and fifty people, all Maya, were practically all born and brought up in the neighborhood. All are familiar with the nearest town on the railroad, many have been to the capital city, but only one or two have ever lived there. Maya is the universal language of ordinary conversation, but about one

fifth of the people also speak Spanish. About as many can read and write, but only a very few do. All grow the corn and beans that they eat, but each man produces more than his family consumes, for part of the crop must be exchanged for textiles, salt, gunpowder and other necessaries which the factories manufacture and sell to the villagers chiefly through itinerant merchants.

Practical activities are closely associated with magical and religious observances. A simplified ritual form of Catholic Christianity exists along with a pagan religion derived historically from that practised by those ancient temple-building Mayas. The planting and harvesting of corn is sanctified by ritual offerings, sometimes highly ceremonial, to the gods who bring the rain and guard the cornfield. Sacred breads are made and dedicated; turkeys are strangled with ceremonial bark beer. The beehives, too, have their special deities and appropriate propitiatory ceremonies. Shamans maintain this ritual, and divine the outcome of sickness or enterprise through crystal-gazing or the counting of grains of corn; but their prestige is waning, and it is shared by the authority of secular leaders who read the newspapers, study horticulture and commit their people to a program of modernization and progress.

The graver problems of life are still regarded as magically caused; sickness, for example, is thought to be produced by evil spirits embodied in the winds, or by the gods who punish failure to propitiate them when the corn is planted or the honey taken from the hive, or by the souls of dead relatives for whom the appropriate ritual has not been performed, or by the enchantments of the sorcerer in the next hamlet. Yet to-day in this village there is always an alternative treatment to that recommended by the shaman: the sick man may send for medicines from the drug store in the town, or he may go for treatment to the modern clinic established by Carnegie Institution at Chichen Itza.

Reference to tradition is still the predominant way to solve difficulties, but it is no longer the only way; the people are becoming used to novelty and experiment. There are plans to establish a cattle cooperative, the advantages of domestic hygiene are stressed in village discussions, there is some experiment in crop diversification, and a road is being built to connect the village with a railroad and the tourist trade. In this village an account of customs means little, unless it is also an account of how these customs are changing.

Our work here has been carried on with the important aid of Mr. Alfonso Villa, the school teacher, who has spent over two years in the village and has learned the Maya language. It has reached the point where acquaintance with the life is sufficient to suggest some of the problems that might be studied.

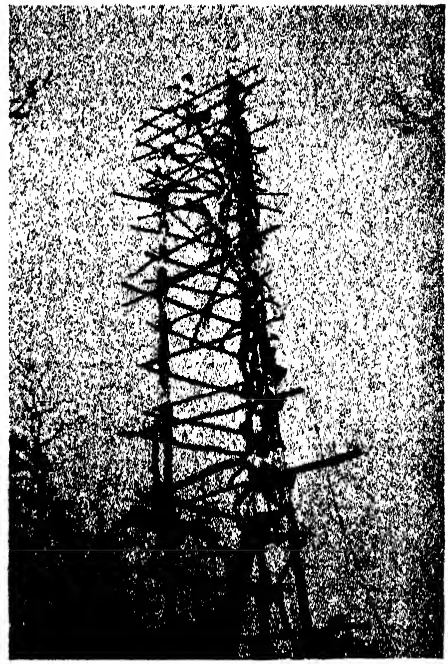
We have a fair account of the principal patterns of activity. We have familiarity with the cadences of life, the ways in which birth and marriage and death are met, and with the ceremonies which mark the rhythms of the agricultural year. The primitive economics of the village has been investigated: we know how much labor goes into raising how much corn, and how much corn is consumed, and how much sold. And we are beginning to have some inkling of the ways in which social changes came about in Chan Kom.

We have in this village the advantages of a situation that is relatively simple. Chan Kom is large enough to include forty or more households and individuals exhibiting a great variety of personalities, but small enough so that it is possible to have some acquaintance with everybody. Only two or three

people leave the village daily, and no more arrive. These arrivals and departures are almost the only means of communication with the outside world, and as novel and interesting information is quickly gossiped about, it is possible to observe the effect of such information on attitudes and practises.

So we have found ourselves experimenting with what might be called a genetic method for the study of social change. The effect of news and of internal events is watched over a period of time. For twenty months Mr. Villa has been keeping a journal, reporting the happenings in the village that have come to his attention. This is now a body of interesting episode, suggestive of what might be studied more carefully, but requiring some more objective and controlled techniques of observation. These episodes are sometimes matters of merely passing interest, but sometimes they involve changes in practises and standards of life. A man goes to the town, and hears a speech about the advantages of socialism and rational living, in which the orator urges the propriety of having two wives, provided only the husband can support them. The villager returns and puts the suggestion into practise; his first wife is enraged and the village is indignant. The man's prestige and patience overcome these difficulties; the new arrangement becomes accepted; after a little other men follow his example and several bigamous households are set up.

A young girl, in response to suggestion from the town and in defiance of custom, leaves her home to take employment in the town as a domestic servant. But her parents have already made arrangements for her marriage; they try to make her return to fulfil the contract, but fail; and the parents of the boy to whom she has been betrothed demand from the girl's parents the value of the food they have supplied for consumption during the ceremonial visits leading up to the betrothal. This claim is supported by the village authorities. The whole matter is discussed by every one; the other girls are particularly interested. But beyond this we can not at present follow the affair. What is the effect upon the younger generation of this first successful instance of a girl becoming independent of parental authority and support?



TOWER ERECTED AT CHAN KOM
TO ENABLE THE PEOPLE TO SEE THE RUINS AT CHICHEN AND SO TO LAY OUT THE LINE OF THE ROAD TO CONNECT THEM WITH THE RAILROAD AND THE CITIES.

Two difficult questions must be answered before material of this sort can be proved to be of lasting scientific importance: Can we learn to report these happenings objectively and with attention to the relevant facts? Will comparison of such happenings yield general knowledge defining the circumstances under which social change is favored or hindered?

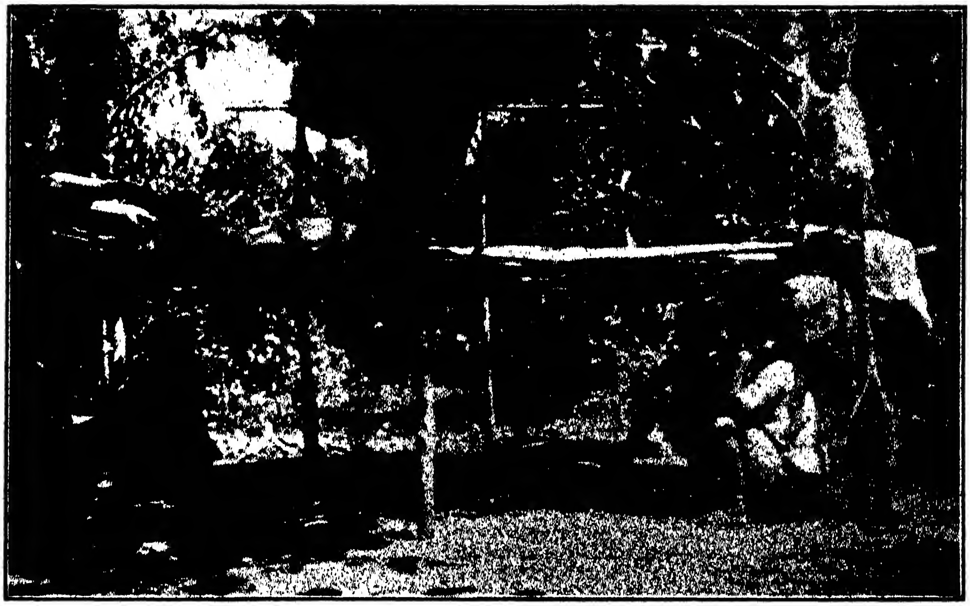
CEREMONY PERFORMED IN CHAN KOM

TO SECURE RAIN FOR THE CORNFIELDS. THE SHAMAN KNEELS AT THE ALTAR; AT HIS LEFT AN ASSISTANT SPRINKLES THE ALTAR WITH THE CEREMONIAL BARK BEER.

It must be taken into account that we, as observers, are ourselves factors bringing about change. Mr. Villa comes to regard his school and its activities as a laboratory experiment that he has set going. Whenever one of the scientists working on one or another of the Carnegie Institution projects visits Chan Kom he is likely to introduce some idea interesting to the people. Dr. Shattuck gave a talk on microbes; the people understood these to be little ants gnawing their vitals; for a few days every one felt them biting away inside and the shamans did a thriving business in exorcism. Dr. Soundground's explanation of the function of vitamins in the dietary made the tomato fashionable for a short time; but a year later the vitamins had become merely part of the local folklore—three little beings, a triad as mystical as the Trinity, one making bones, one flesh and one blood.

As we become increasingly interested in the contemporary life of these village people and the changes going on in this life, we come more and more to look upon their world through their own eyes. It is then plain how different is the historical meaning of what they do from its actual present meaning. To the student of archeology, who has seen in murals on ancient Maya temples at Chichen Itza representations of the four priests known as Chacs holding a human being by the limbs that he may be slain in sacrifice, it is especially interesting to find the Chan Kom people designating by the same name four men who hold by the wings and legs the turkey about to be killed as an offering for the gods. But the villagers are oblivious of the historical origins of this custom, and it means no more and no less to them than does the act of crossing oneself, or any other piece of ritual in their mixed pagan and Christian religion.[3]

[3] But the Shaman-priest himself told us that "in the old days it was a human being, and not a turkey."



THE FOUR BOYS WHO IMPERSONATE FROGS,
CROAKING TO BRING RAIN, AT THE RAIN CEREMONY IN CHAN KOM.

As archeologists, we look upon these Mayas as the descendants of the builders of the temples, but they do not so look upon themselves. They have no sense of connection with the old cities, except that Coba has a vague prestige, a certain uncanniness; certain gods and mythical monsters dwell there, and shamans who have visited these ruins have there secured unusual powers. Both Chichen Itza and Coba are mentioned in ritual prayers, but the meaning of the words uttered is not always intelligible to the average listener.

Some of the interest the present-day Indians exhibit in the old ruins may be a recent development rather than an old survival. There is a contemporary folktale about a serpent, named Xkukican, who once lived at Chichen Itza and was wont to devour children—this may very well be a vestige from the old human sacrifice and the cult of the plumed serpent (Kukulcan). On the other hand, contemporary explanations as to the meaning of some of the old carvings at Chichen Itza, or stories that make use of the ancient Ball Court as a race track for folk heroes, do not necessarily involve any such survival, but may simply be the result of myth-making since the Conquest.

At any rate, to the present-day Maya, the builders of these great temples were of quite another race, no ancestors of theirs. They were the Itzaes, great people of supernatural powers who dwelt a long time ago. Some villagers confuse these Itzaes with still another race, a dwarf people, who had the magical knowledge that made possible the building of vast cities of stone. They knew the whistles that caused these stones to leap into place of their own accord. But through their carelessness, or impiety, this knowledge was lost and the dwarf people were all destroyed. This happened long ago, "before our grandfathers were here."

And to-day any vestige of the ancient Maya, having for the Maya of to-day nothing of its old meaning, is simply

uncanny, or downright dangerous. Fragments of obsidian knives are the sling stones of the gods who guard the cornfields, and clay idols are evil midgets that it is best to smash where they lie, lest they come alive at night and work harm to men. One ceremony, occasionally performed, takes place at a stone ruin of ancient days, and has for its purpose the propitiation of these pottery goblins.

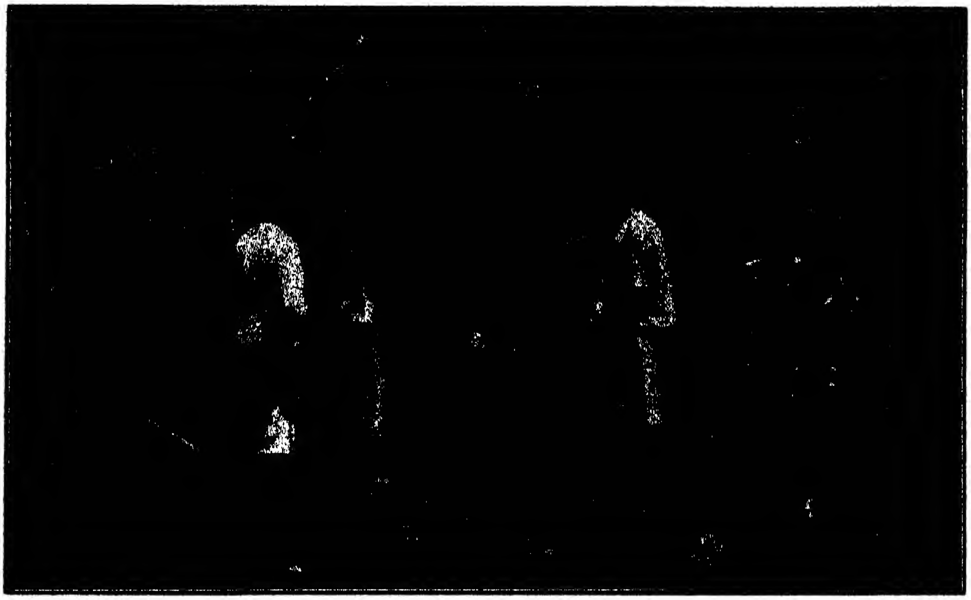
Such concerns occupy only a small corner of the villagers' interests. In our studies we are seeking to look on life as they do, and to see things in the perspective and with the sense for relative importance which characterizes their own outlook. To know a culture is to know how its objects and its actions appear, not to anybody on the outside, but to the people who deal with the objects and perform the actions.

Toward this goal progress is made through intimate association with the people, the sort of sympathetic, yet detached consideration to which Mr. Villa has been devoting so many months. There seems to be no short cut to intimate acquaintance. Circumstances may be more or less favorable, but at the best much time is required. Nevertheless, one feels the need for some method of investigation that will give to this intimate exploration some degree of objectivity, that will result in materials of permanence and consultability. Here again we are fumbling for useful devices.

Following the suggestions of others we are especially attentive to revelations of attitude and view-point through the experience of particular individuals. These villagers are human beings with the same tendency to shame, pride and conceit that other people have, and they most reveal their culture when they let us see what it is they are characteristically proud of, or ashamed of. Spontaneous comment on current situations is illuminating, but it is fragmentary and fugitive. Longer connected statements of personal experience are harder to obtain, and when obtained are apt to be less spontaneous. Still, we have one autobiographic document of about ten thousand words from a man of this village, that puts a lot of content and added significance into the bare statements as to custom and attitude set down in other parts of our notebook.

For example, although we were aware in general terms of the importance of the marriage settlement in fixing the social position of the couple, it was not until we read this man's account of his own marriage, apologetically commenting on the small amount of property involved, that the real significance of the custom appeared. This autobiography also brings out very vividly, in terms of the life experiences of one man, the conflict between the younger more progressive element in Maya society and the authority of the shamans, who, in receiving rum and money in connection with certain traditional customs which they supervise, represent a conservative vested interest in the village life.

And we had little idea of the limits of the natural community to which local loyalties attach until we had this man's own account of how the local fatherland, including perhaps half a dozen villages and their satellite hamlets, was aroused to concerted military action by disorders incident to the recent revolution. Then the distinction between "our people" and all outsiders was made perfectly plain in the roster of pueblos that fought together. It is interesting to the student of history, incidentally, to note that this little world of patriotic attachment to-day corresponds very closely with one of the several Indian principalities, or *cacicazgos,* into which the old Maya confederacy broke up just before the coming of the Spaniards.



THE MAN IMPERSONATING THE GREAT RAIN-GOD (KONKU CHAC) RECEIVES HIS CUTLASS AND CALABASH, WITH WHICH HE IS TO MIMIC THE LIGHTNING AND THE RAIN.

The scientific usefulness of these methods of inquiry will be better tested when we shall have tried them in some of the other communities we hope to study. During 1932 we plan to carry on studies in one or more communities in or near the capital city of Merida. Here again there is a problem in wisely selecting the samples to be studied; it is apparent that there are communities of different sorts: for example, colonies of city-wise shop-workers, as contrasted with settlements on the outskirts of the city of Indians only recently come from the country villages but finding their employment in the city itself. We hope to find in such communities other aspects of the process of transition observable in Chan Kom.

Looking in the other direction from Chan Kom, southward and toward the more primitive rather than northward and toward the more civilized, we find in the territory of Quintana Roo a group of villages in which Mr. Villa is to begin work during the coming year. These are villages of Mayas who turned their backs on the towns and the ways of white people after the race war that took place in Yucatan in the middle of the last century, and who still remain relatively isolated from the white man's civilization. Here it is probable that we shall find much the same customs as in Chan Kom, but a very different social setting.

A cursory impression suggests that differences in customs are minor: the women wear necklaces of Guatemalan coins instead of the gold chains of Yucatan; the dead are buried not in Christian cemeteries but in the streets or under the floors of houses; the patriarchal extended family organization is perhaps better developed than in Yucatan; and in the mixed-Christian religion the cult of the cross probably plays a more important rôle.

But in outlook on life these Mayas of Quintana Roo are probably very differ-

THE SCHOOL GARDENS AT CHAN KOM,
PREPARED ACCORDING TO MODERN HORTICULTURAL METHODS.

ent from those of our first village of Chan Kom. Contact with the outside world is not through the teacher and the tourist, but through the traveling merchant and the gatherer of chicle. This fact, and the traditions of hostility toward the Mexicans, maintain in them an aloof and independent attitude. Organization is tribal. The several villages are united in a military-religious federation under the symbol and control of a "talking cross," an oracle enshrined in a little interior village, that delivers, mysteriously, omens and warnings that are carried to all the subsidiary villages by men drawn in rotation from each hamlet to do vigil at the seat of priestly government.

In this part of the Maya world, one imagines, change is thought of as undesirable, and the prestige of the shaman is not seriously challenged. Yet these communities are changing, too, probably not as rapidly as is Chan Kom, and in response to different, and—from the point of view of the whole process—earlier influences, such as the first school and the gatherer of chicle.

This statement as to our purpose, and as to some of our perplexities, may be brought to an end by a summary of what we may reasonably hope to obtain through these projected studies.

There will result a body of information as to the customs of the Maya in certain parts of the Yucatan peninsula. This information will have whatever intrinsic interest such ethnological materials ever have. Some of it may have a direct practical value in enabling Mexican administrators, educators and reformers to deal more effectively with their problems.

Mr. Villa has come to understand the difficulties in the way of educating the simple villagers to whom he has been devoting the years of his youth. He was instructed to teach them reading and writing of Spanish by methods devised in the capital and sent down in printed instructions—a people who had nothing to read and little desire to do

so, and whose domestic language was Maya, not Spanish. This he accomplished, but he soon saw that for his successful pupils literacy was like the learning of a trained dog—diverting, but unimportant. In fact, in making the census enumeration this teacher set down as able to read and write Spanish a score of persons who were in another column recorded as unable to speak that language. The educational policy of Mexico has been remade in response to suggestions derived from an acquaintance with the interests and customs of that country's backward folk; and, generally speaking, the success of reform and control increases with the knowledge of the people.

Some of this information as to Maya customs may be of interest to the historian of American Indian civilization, especially as it may throw light on the life of ancient Maya. But we must be cautious in drawing conclusions as to ancient practises from contemporary customs. Maya culture has undergone very great changes since the Conquest. The old calendar, writing and quasi-philosophical religion were perhaps never complete possessions of the common Indian; and therefore it is no wonder that the Spaniards easily destroyed all this. But simpler cultural elements, originally probably widely present, have likewise disappeared. The ancient Mayas ate dogs, for example, but the Maya Indians of my acquaintance regard the idea with the same distaste with which most of us regard it.

Nevertheless, some light on ancient Maya life may be expected to come from these investigations, especially in so far as attention is paid to the less civilized groups and to the older men. An example of how such light may be thrown may be given. In some of the old Maya manuscripts the name of a certain deity occurs without explanation. The same

TO DRIVE OUT DISEASE-BRINGING WINDS

FROM THE BODY OF AN AFFLICTED GIRL, THE SHAMAN STROKES HER WITH CERTAIN LEAVES, MEANWHILE RECITING PRAYERS TO THE SAINTS AND TO THE PAGAN GODS.

A CEREMONY FOR THE GODS WHO GUARD THE CORNFIELDS, PERFORMED TO RELIEVE THE OWNER'S SICKNESS. THE SHAMAN CONSULTS HIS CRYSTAL TO DIVINE THE WILL OF THE GODS.

name occurs in present-day Maya prayers in a context explaining that the god was a patron of the bees and himself thought of as a giant bee. This makes it at least possible that the ancient god of this name was of the same character.

Where outside factors hold behavior relatively constant, as for example the time and labor used in growing corn and burning lime, information derived from present-day life may be directly transferable. Earl Morris, Carnegie Institution archeologist, has made good use of this material, investigating the time and labor required in burning lime and cutting wood, as practised by the contemporary Maya, in order to throw light on the man-power necessary to build some of the stone structures at Chichen Itza.

We have computed the amount of land necessary to support the contemporary Maya population of the village we are studying and have reached an estimate of six hectares of cultivated land per year per inhabitant. As land is cultivated there on an average of only two years out of seven the total amount of tillable land which must always be available is about twenty-one hectares per inhabitant. But before these figures can be used as the basis for an estimate as to the population that could be supported on the peninsula in ancient days it will be necessary not only to determine that this is a fair sample for the entire region, but also to take into account changes that have taken place in the economic life of the inhabitants.

The introduction of iron tools is one such factor, but others even harder to estimate are changes in the dietary, notably the introduction of poultry and some beef and pork, and also the introduction of factory-made textiles and other goods which must be paid for out of excess corn produced. It may be that in the old days a man had to raise twice as much corn as he and his family consumed, as is the case now, but we would have to know this before the fig-

ures could be used to draw conclusions as to the maximum population the peninsula would support under ancient conditions.

Perhaps we shall get more help from the students of the ancient Mayas than we are able to give them. Had we not known, for example, of the importance of the idea of the four directions in ancient Maya thinking, it might not have occurred to us to note just how many piles of stones, each surmounted by a cross, are placed around Maya villages. Once we had investigated, and there had proved to be four—whether there be four or fourteen roads leading into the village—it was easy to push the inquiry farther and determine that the contemporary village in the region was oriented with respect to the four corners of the world, each still under the protection of a particular god.

But more important than any amount of information, we may hope for some improvement of the methods of study of culture changes. If we can add anything to such methods, we shall have justified the expenditure. For then there will be something that can be taken away from this field and used in others; there will have been some sharpening of a tool or two with which to attack the problems of contemporary circumstance.

If the study of several communities along the range of civilization is carried out as planned, it should itself constitute a sort of case-history of the process of civilization. If the several communities are studied in such terms as to assure the student that the essential modifying factors have been taken account of, this series of related studies will furnish a background for further inquiries into special problems, as, for example, the growing function of money, or differences in the age-groups and personality types from which leaders are drawn, in communities at varying stages of culture.

This list of possibilities and aspirations may be extended to include the hope that in this attempt to develop methods for the study of culture in Yucatan, our developing interest and skill may go along with that of the people of Yucatan themselves. If some of them come to study the contemporary people, as they are already studying the ancient people of Chichen Itza and Uxmal, the value of our own studies will become a permanent value.

There is a great need for trained students of contemporary cultures, and those who are already on the ground, speak the language and are stimulated by the practical problems that concern them directly have in these respects superior qualifications for such work, as compared with foreigners. We hope such students may appear in Yucatan. Science is not so much going some place to get facts, as it is continuing and developing ways of dealing with experience. The important task is to get these ways going in the new places, and to improve them everywhere.

# EARLY HISTORY OF PETROLEUM IN NORTH AMERICA

By Professor CAREY CRONEIS

WALKER MUSEUM, UNIVERSITY OF CHICAGO

WHEN a country, a family, a science or even an industry is "on the make," there is no time and little inclination for writing its history. But when an empire finds "its place in the sun," when a dynasty is finally established, when a science is widely taught and extensively employed, or when an industry becomes fundamental, then comes a "breathing spell," in which their achievements begin to be recorded. Only then are the details of the early struggles which made them possible exhumed from the contemporary, and often contradictory, accounts. Indeed, the very appearance of annals is to the cynic a tacit confession of the early stages of desuetude.

That the oil and gas industry, and petroleum geology as well, are not now on the crest of the wave, no one will deny. But that they are already destined to go the way of the Roman Empire or the Medici family, only a few of the most pessimistic would affirm. Nevertheless, the industry and the profession have now reached that stage of robust maturity and (just now, enforced) leisure in which they are interested in their own early beginnings. This is evidenced by the fact that in the last few years a number of geologists, engineers and even captains of industry have been gathering together and publishing, chiefly in technical journals, some of the pertinent data regarding the early history of petroleum and petroleum engineering in North America.

Their accounts have dispelled, from the minds of the experts, many of the misconceptions and not a little of the misinformation that has become so inseparably linked with the rapid growth of any industry or profession. But additional somewhat iconoclastic data regarding the first years of commercial oil production are contained in the newspaper accounts of that period, and in a number of essentially contemporaneous books. Inasmuch as some of these volumes, as well as other relevant facts, are now unavailable, even to the average technologist, and because the layman has never really been informed of the glamorous pioneer days of one of the greatest of the modern industries, there is summarized here a few of the less well-known data concerning that early period. But before plunging into these historical accounts let us briefly review a few of the steps leading to the modern development of this megalomaniac industry.

In our present-day industrialism, oil and gas are regarded as indispensable, yet less than 75 years ago not one drop of oil nor a cubic foot of gas was produced in the modern sense of the word, though a few "gas springs" were known, and a little oil was skimmed from seeps for medicinal purposes. The pioneer wells of the late fifties of the past century were essentially hand drilled; those of to-day are put down by the most elaborate machinery. The early wells cost a few hundred dollars; many of those drilled to-day cost more than one hundred thousand, and a few have required a quarter of a million dollars for their completion. "Colonel" Drake's discovery well of 1859 yielded 25 barrels of oil a day from a depth of less than 70 feet; some of the modern

producers have a potential capacity of more than 200,000 barrels a day, and some have tapped the oil sands at depths of more than a mile and three quarters. The total world production of oil seventy years ago was only a few thousand barrels, but, owing to the increasingly feverish rate of production, "Old Mother Earth" has now yielded approximately twenty billion barrels of the liquid gold, of which about 65 per cent. was produced in the United States. In fact, at the time of peak production (August, 1929) this country alone was producing oil at the rate of more than a billion barrels a year.

A billion barrels of oil a year is an almost inconceivable amount of petroleum, but even this does not represent the total potential production of our prolific fields. Man in his avidity has overdrilled most of the known productive areas until at many places the derricks at a casual glance seem to be in lock-step. As a consequence, far more wells have been drilled than actually were necessary for the optimum recovery of the oil. Thus it happens that the statement, "A dollar and a half has been spent for every dollar's worth of petroleum produced," is not far from right. As a further consequence of over-drilling in some fields, several states have found it necessary to prorate the production of each of its wells. This proration is especially effective in California, Oklahoma and Texas, the great oil triumvirate, where production is now limited to about one half capacity.

In spite of our seeming deluge of oil, and the relatively recent price of a few cents a barrel in the East Texas field, many a disillusioned prospector will tell you that "oil and gas, like gold, are where you find them." So they are! But through the intelligence of man in general and of engineers and geologists in particular, and, I must confess,

"COLONEL" EDWIN LAURENTINE DRAKE, ABOUT 1865.
FROM AN OLD ENGRAVING.

through sad experience as well, we have learned that they are invariably found in "certain places."

Through the efforts of Dr. I. C. White, for many years state geologist of West Virginia, it became apparent (by 1885) that the most prominent of these "certain places" are localities in which the rocks are up-folded into the structural condition known to the geologist as an anticline. In other words, disregarding entirely the highly controversial subjects of the origin and migration of oil and gas, these substances generally accumulate in porous beds which are bowed upward. Once this principle was established, scientific drilling was limited to the relatively small and fairly easily determined anticlinal areas; and thus the percentage of dry holes greatly decreased.

The claims of Thomas Oldham, T. S. Hunt, H. D. Rogers, E. B. Andrews, Sir William Logan, Alexander Winchell and others for priority in connection with this anticlinal theory often have been aired. But, as J. V. Howell says, "It remained . . . for I. C. White to put in clear and concise form, with ample

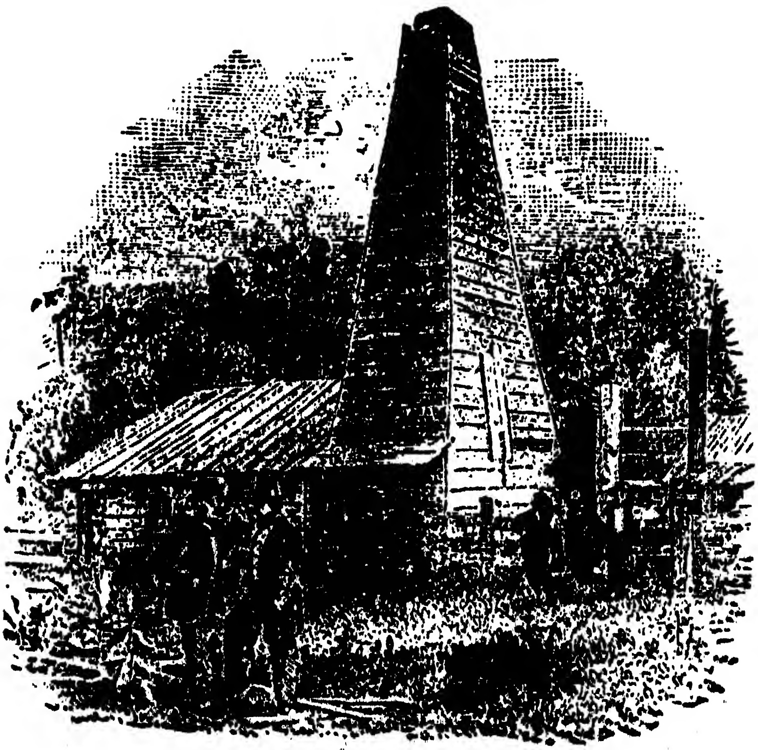
supporting evidence, the theory as it is now known, and furthermore to apply it widely and with undoubted success." White himself has generously acknowledged that it was Mr. William A. Earseman, of the Forest Oil Company (later a part of the Standard Oil Company), who, although not a geologist, pointed out to him that a number of gas wells were located near points on maps where the Geological Survey of Pennsylvania had drawn anticlinal axes.

But nearly twenty years before White became interested in anticlinal control, a Canadian public land surveyor, Henry West, fully comprehended the practical value of this principle. This is conclusively indicated by a number of facts. On the title-page of his "Geology, Oil Fields, and Minerals of Canada," dated May 1, 1865, he states that the accompanying map shows "each lot, concession, and *oil bearing anticlinal.*" In his preface he says further concerning the map that:

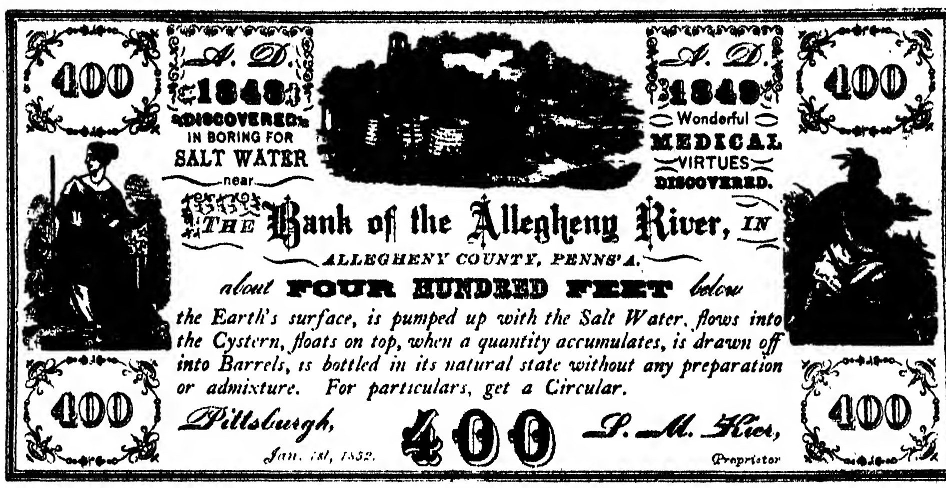
> The different formations within that area are distinguished upon it by colours; and the main anticlinal axis in which (and its subordinates) petroleum may be expected to be found, are also marked as bands, from the east, to where they make their exit in the western extremity of the Province, at the upper end of Lake Erie, etc.

Later, he continues with some very definite statements. The italics are his:

> Scientific reasoning and inferences, which subsequent practical experiments have so far fully confirmed, has demonstrated that *it is at, along, or near the crown of these anticlinals,* in hydrocarbonaceous bearing formations that liquid *petroleum may be expected to be found.*
>
> Some of the springs in Western Canada appear to be on the line of the great anticlinal as before indicated, and others are, no doubt, either on, or connected with subordinate undu-



"DRAKE'S FOLLEY"—THE DISCOVERY WELL.
FROM AN OLD ENGRAVING.




THE LABEL THAT STARTED AN INDUSTRY

FACSIMILE OF THE ORIGINAL.

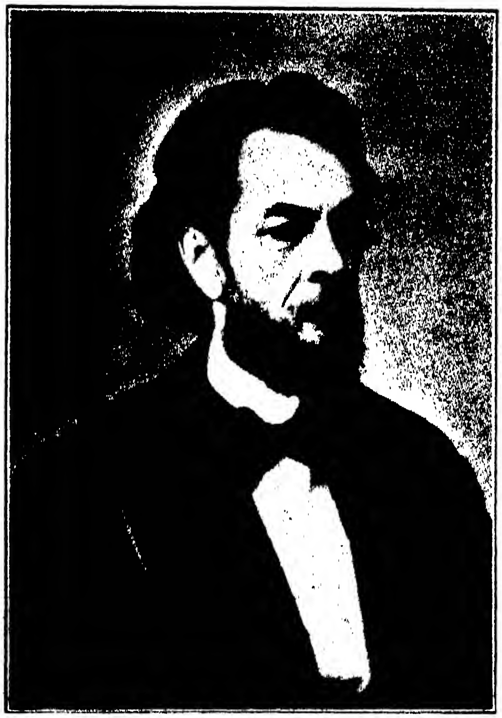
lations; for, the oil being lighter than water, and permeating with it the strata, naturally rises to the highest part, or crown of the different anticlinals, where it is confined, and from whence it escapes into the overlying deposits, or to the surface by natural rents, cracks, fissures, or borings. By the sinking of wells, and the aid of artificial borings, into the underlying oil bearing rocks below, and the recently discovered improved modes of refining it, as well as the various purposes of life to which its uses have been and can be applied, has been the means of greatly increasing its supply and augmenting its demand. Rock oil has therefore created quite a mercantile revolution in the article of light alone; and caused an almost unparalleled new branch of manual, mechanical, and speculative industry to spring up within a very short period.

It therefore becomes a matter of the greatest importance to enquire, and if possible, determine where these anticlinals and their subordinates are located in oil bearing formations.

West gives not a single reference, so that it is impossible to ascertain whether or not these ideas are original with him. It is just possible that he borrowed some of them from Hunt, whose somewhat similar views had appeared in print four years previously. But, at any event, no one at this early date had had so clear a conception of the importance of structure in the accumulation of oil and gas, nor of the method of outlining such structures by means of drilling data. This is well demonstrated by the following paragraph, in which the italics are West's:

I shall therefore conclude this part of my subject with the advice that, having pointed out the formations and localities in which natural oil is known to exist, and may be expected to be found; and seeing also that reason and experience have confirmed the fact, *that, it is at or along the crown of these anticlinals that petroleum centers or collects; we must, in order to be successful, look for these anticlinals in oil-bearing formations. They are sometimes (where not covered over by too much drift) marked by slight elevations on the surface; but it is only from a minute examination and measurement of the angular inclinations of the sub-strata that the precise locality of the anticlinals can be definitely determined. This is an easy process when exposures occur, or facts noted, in deep borings. For if, from the same surface level, several borings are made in an oil-bearing neighborhood in various given directions, and the several depths of the same strata noted, it would be easy to determine the inclination of the underlying strata, and where the crowns of the anticlinals are located, and may be found, and where borings may reasonably be expected to be successful in the production of liquid petroleum.*

The revival of old depleted oil wells is another petroleum practise which is



GEORGE H. BISSELL ABOUT 1870
FROM AN OLD WOODBURYTYPE

generally considered to be a recent engineering triumph. Indeed, A. Beeby Thompson, in 1925, said, "Previous to the year 1905 the Baku oil fields of Russia offered a very favorable field for air lifts. . . . In 1899 the first experiments with an air-lift were made under the supervision of the author."

A much earlier instance of the revival of old wells, and the use of a primitive, but apparently effective sort of air-lift is recorded in the following Pennsylvania newspaper account of 1865, reported in "Derrick and Drill." The italics are mine.

The large flowing-wells have generally stopped after twenty-five or thirty months' flow. Some few have continued, with diminished volume, over three years. The pumping-wells have averaged about the same duration. In 1863, and until the latter part of 1864, comparatively few new wells were sunk. During this period many wells gave out, and many were abandoned. It was never ascertained, until within the past eight months, that wells which had ceased to produce oil could be made to resume their yield. This fact is now established. *A great many wells that were considered exhausted have been resuscitated, and are now yielding very considerable quantities of oil.* Among the noted instances are the Empire well, on the McElhenny farm, *now flowing, under the pressure of an air-pump, a hundred barrels per day;* the Buckeye well on the same farm; the old Sherman well, on the Sherman flats; and the old Phillips well, on that farm, has spontaneously resumed its flow, after occasional interruptions, since October, 1861. Wells are caused to flow spontaneously by the pressure of naphtha gas within the earth being greater than the pressure of the atmosphere. When this greater pressure is reduced by exhaustion to an equilibrium with the atmospheric pressure, the flow ceases until artificial pressure is applied, or until a fresh accumulation of the gas causes a resumption of the flow. . . .

It may be safely said, then, that it is, up to this time, not the exhaustion of the oil, but the exhaustion of the gas which elevates the oil, that has produced an embarrassment to oil mining which threatened at one time to hazard its success, but which is now obviated by the application of new and efficient inventions.

The famous Professor Henry D. Rogers, himself, may have written this account. At any event, in 1865, the same year the quotation was written, he gave a paper before the Philosophical Society of Glasgow, in which at one point he used essentially the same words as those of the last paragraph above to propound this modern idea.

The place of "Colonel" Edwin Laurentine Drake (1819–1880) in the annals of petroleum is well established, but in recent years only a few writers have cared to give any but the legendary story about him. Moreover, the importance of George H. Bissell and the rôle of Samuel M. Kier in the early history of the industry are now essentially forgotten. The interrelationship of the work of these three men makes an interesting story. In part, it can be reconstructed from newspaper accounts. A writer in the *Meadville Republican* of March, 1865, signing himself "W. H.,"

sent the following letter from Alleghany College:

Having occasion recently to look into the origin of refined petroleum, and its application as an illuminator, I was surprised to find that the man who was unquestionably the first to apply refined petroleum to illuminating purposes is entirely overlooked in the published histories. This is the case in Appleton's Cyclopedia, which, however excellent in other respects, needs some amendation in this. For the sake, therefore, of historical justice, and lest it should happen on this (as it has happened with some previous valuable discoveries) that due credit should not be awarded to the proper person, I propose to make a brief statement of facts in behalf of a very worthy but modest man, who is certainly entitled to the honor of having first introduced this almost incomparable illuminator to the public. I refer to Mr. Samuel M. Kier, of the city of Pittsburgh.

The facts as stated in Appleton are substantially these: That the success attending the manufacture of Coal-oil, and the identity of the crude coal-oil with the natural petroleum, suggested the idea of applying to the natural oil the same methods of purification invented for the artificial; that the first movement of this kind was made by Eveleth & Bissell, of New York, in 1854, who tested some oil from Oil Creek, the result of which was satisfactory. After this no progress was made for some time. . . .

The statements I have to make in favor of Mr. Kier's priority are these, abridged from valuable data in my possession. About the year 1849, Mr. Kier discovered oil coming up from one of his salt-wells near Tarentum, on the Allegheny River.[1] After a time it accumulated in the receiving tank to such an extent as to become troublesome; and not knowing what use to make of it, he let it run away. Oil was discovered about the same time coming up from another salt-well (Mr. Peterson's) in the same neighborhood. About six months after the discovery, Mr. Kier conceived the idea of putting it up as a medicine, and to prevent competition, purchased also the oil from Mr. Peterson's well for five years. Some of the oil was then disposed of, but Mr. K. found in the course of a few months that he could not thus use all the oil the wells were producing, and did not know what to do with the surplus. He sent a portion of it to Philadelphia, to Professor Booth, to have it analyzed, in hopes of finding some other use for it. When Mr. Kier went to see Mr. Booth, the professor informed him that he found the largest portion of it naphtha, which, he thought, would be useful in the gutta percha manufacture as a solvent. Mr. K. went to New York, had it tested, found it would not answer, and reported accordingly to Professor Booth. The professor then told him that if he could get a suitable lamp constructed to burn it, it would make a splendid illuminating oil. He also gave him instructions how to distill or refine it. Mr. K. went home and immediately got to work, put up a little refinery, and informed the mechanics what kind of lamp he wanted. Soon two men came in on the same evening, each having a lamp in his hand. They lighted them, and such was the effect, that each one claimed the superiority for his own manufacture, and they commenced quarreling over the merits of the respective lamps. Mr. K. reconciled them by concealing the excellencies of both, and suggested a partnership. They opened a lamp store on Wood Street, Pittsburgh, Mr. K. furnishing the oil. They proved, however, to be "crooked sticks," who soon quarreled again, and first one left and then the other, leaving the whole business on Mr. K.'s hands. Such was the demand for the oil now, that he could not get enough from his wells. But he thus used all he could obtain from his own and other salt-works for about five years, from 1850 to 1855. The year before this latter date is the one named in Appleton as the time when Eveleth & Bissell made their experiment with oil from Oil Creek. Mr. Bissell gets the credit of first conceiving the idea of boring for oil. He, and perhaps other parties interested, sent out Mr. Drake, who sunk the first well on Oil Creek. This was, I think, in 1859. Before commencing his operations, Mr. Drake went to Mr. Kier's wells on the Alleghany, examined them, and hired a blacksmith who was then working for Mr. Kier to go and bore for him. The result is well known. Mr. Drake struck oil at about seventy feet, from which dates the great oil excitement of the day. But it may not be known that Mr. Kier bought the first oil that came from Mr. Drake's well, and refined it at his refinery. From these facts it would seem that Mr. Kier, of our own good commonwealth, prompted and assisted by Professor Booth, also of our State, refined and used refined petroleum, as an illuminator, for from four to five years before the first well was sunk on Oil Creek. This many of the purchasers of Kier's "carbon oil" in Pittsburgh and elsewhere can testify. Before oil was obtained by boring on Oil Creek, the writer himself brought here, from Mr. Kier's

[1] Other documents show that the Kiers, father and son, had been troubled by oil in their salt wells for "many years" prior to 1849.

establishment in Pittsburgh, the first "carbon oil" and lamp that ever came to the place.

But in addition to being a pioneer refiner as well as the man who supplied the mechanic to bore Drake's well, Mr. Kier was indirectly responsible for Bissell's very idea of *drilling* for petroleum. This results from the fact that the "medicinal oil," which Kier put on the market in 1849 at fifty cents a bottle, carried an extraordinary label which was to play an important rôle in the lives of Bissell and Drake. But before going further into this story it is necessary to outline some of the early activities of Mr. Bissell, who, although now essentially forgotten, was without doubt the guiding spirit in the embryonic days of the petroleum industry.

George H. Bissell (1821–1884) was born in Hanover, New Hampshire, was graduated from Dartmouth College in 1845, and was for a short time professor of Greek and Latin at Norwich College. After newspaper service in Cuba and later at New Orleans, he became the superintendent of public schools at that city. In 1853 impaired health forced him to return north, where he formed a law partnership with J. G. Eveleth in New York City.

Calling on his old tutor, Professor Crosby, at the latter's office at Dartmouth, he saw there a bottle of petroleum from Oil Creek, Pennsylvania. This oil had been brought to Hanover by another Dartmouth graduate, Dr. F. B. Brewer, who, having used it successfully in his practise, had submitted a sample for analysis. Mr. Bissell's active mind at once visioned the possibilities in this product, and, with Mr. Eveleth, he immediately purchased for $5,000 what were thought to be the chief oil-lands of Pennsylvania. Then in 1854 these two men organized "The Pennsylvania Rock Oil Company," the forerunner of all the modern oil corporations. Thus, modestly, began a present $4,000,000,000 a year industry!

The company attempted, without much success, to develop their lands by means of trenching for the oil. Not discouraged by the small amount of petroleum obtained in this fashion, Bissell and Eveleth employed Professor B. Silliman, Jr., of Yale, to analyze their product. Professor Silliman's report, published in 1855, attracted considerable attention in the East, and led to the reorganization of the company with Silliman as president.

Some idea of the difficulties attending the early stages of organization may be gained from a letter written from New York on November 6, 1854, to the same Dr. Brewer who brought the first sample of oil to Dartmouth. The letter follows:

*Dear Sir:* We have had to encounter many obstacles in the way of organizing our joint-stock company, and shall be unable to get out our papers at the time originally proposed.

Mr. Eveleth will go on at the earliest possible period and will then be prepared to arrange everything to our mutual satisfaction. I do not think, however, that it will be possible for Mr. Eveleth to arrive in Titusville before the 18th or 20th inst.

We have obtained our stock-books, certificates of stock, signs, etc., etc., and have done everything to insure success when we fairly get under way. We have forwarded several gallons of the oil to Mr. Atwood of Boston, an eminent chemist, and his report of the qualities of the oil and the uses to which it may be applied are very favorable. Professor Silliman of Yale College is giving it a thorough analysis, and he informs us that so far as he has yet tested it, he is of opinion that it contains a large proportion of benzole and naphtha, and that it will be found more valuable for purposes of application to the arts than as a medicinal, burning or lubricating fluid.

Our expense of a thorough analysis will be very heavy; but we think the money will be well spent. We send you a proof-sheet of our certificate of stock. The book will be printed of course on bank-note paper.

Let us hear from you at your earliest convenience, and believe us,

Very truly yours,
EVELETH & BISSELL

There is no doubt that Silliman's report, although certainly not prophetic, really determined the economic value of petroleum, since it proved that for many purposes it was superior to coal oil. His exhaustive analysis, which cost $1,200, was paid for entirely by Bissell and Eveleth. Inasmuch as they were only moderately wealthy men, their faith in the future of petroleum, in that earlier period of depression, must have been very great.

The value of their product now being established, their only difficulty was in enlarging the supply. But this, indeed, seemed impossible, for more elaborate trenching had failed to increase their yield. It was at this time that Mr. Bissell again showed himself to be a real pioneer by arriving at an idea. As J. T. Henry, an essentially contemporary writer, has said:

It was the idea of obtaining Petroleum by means of artesian wells. It was a simple thought, but significant—a thought which, as Professor Silliman remarked, was the one of all others most naturally suggested by the various phenomena that had attended the discoveries of Petroleum in the saline of the Muskingum and Kanawha, the first idea that should have been suggested to a mind cognizant of all these circumstances; and yet, though himself editor-in-chief of the periodical[2] in which the circumstances were described, he very candidly confessed, that throughout the five months he was prosecuting the analysis, the thought of artesian boring never once occurred to him. And yet of all in any way connected with these first transactions, he was the only one of whom we had a perfectly reasonable right to expect such an idea; but Professor Silliman's interest in the matter terminated with the conclusion of his elaborate analysis, for though he perfectly comprehended its value, he never expected to see it obtained in any great quantity, and the two hundred shares of stock he held were given him in order to make him president of the company, and thus secure the prestige of a name renowned in science.

According to contemporary accounts, which, of course, may be apocryphal, Mr. Bissell arrived at this idea of drilling for oil in a peculiar fashion—and here Mr. Kier again enters the story. On a hot day during the summer of 1856, Mr. Bissell sought the shade of a Broadway drugstore awning. In the store window he noticed a remarkable show-bill lying beside a bottle of Kier's Petroleum.

His attention was arrested by the singularity of displaying a four-hundred-dollar bank-note in such a place; but a closer look disclosed to him the fact that it was only an advertisement of a substance in which he was deeply interested. For a moment he scanned it, scrutinizing the derricks and remarking the depth from which the oil was drawn, till instantly, like an inspiration it flashed upon him, that this was the way their lands must be developed—by artesian wells.

The idea was simple—at first it may also seem to have been self-evident, but reflect that the mind which grasped it must also have taken in a better conception of the philosophy of the existence of Petroleum than had any other mind before. When Mr. Bissell disclosed his theory to his partner that gentleman embraced with enthusiasm.

But legal difficulties in connection with the lease, which is a story in itself, and various other delays found little accomplished by early in 1858. At this time Drake at last comes into the picture. His true position is shown by an account written at Titusville by one who knew him.

Mr. Townsend, then President of the Company, in lieu of Professor Silliman resigned, employed Mr. E. L. Drake, whom, in the darker days of its prospects, he had cajoled into purchasing two hundred dollars' worth of his own stock for the ostensible purpose of going to Titusville, to rectify the oversight mentioned in the lease, though the real object was not less to have him inspect the locality with a view of what followed, while it might be done at the expense of the Company. . . .

Mr. Drake, though an intelligent gentleman, was the last one to choose for the performance of legal business, as no occupation of his life had prepared him for such duty; besides in order to give a pompous turn to the transaction in the eyes of the backwoodsmen, the legal documents, together with several letters

[2] *American Journal of Science.*

were mailed to "Colonel E. L. Drake, care of Brewer, Watson and Company," before ever the man left New Haven.

The title was the pure invention of Mr. Townsend who generously acknowledges his *pius fraudum*, and in the oil region and elsewhere, he has ever since been known as Colonel Drake. . . .

Meanwhile the Pennsylvania Rock Oil Company was having still other difficulties, and thus on the 23rd of March, 1858, there was formed another association designated as "The Seneca Oil Company."

The basis of their association was the lease. Mr. Drake appeared as the principal stockholder; but no stock was ever issued. It was in effect only a partnership, the members of which sought protection against each other under the laws for joint-stock companies. From the little influence he possessed in the management of their affairs, it is evident that Drake could have furnished but little of the capital. He was not in a situation to do so. For eight or ten years previous he had been a conductor on the New York and New Haven railroad, at a salary of seventy-five dollars per month, and the little he had been able to save from such a pittance had been swept away by an unlucky investment the year before.

Drake, engaged at a salary of $1,000 a year, arrived in Titusville with his family on about May 1, 1858. But for various reasons the well was not started until the middle of June, 1859. And then after many delays occasioned by the caving of surface material, Drake, about in mid-August, tried the experiment of driving an iron tube through the sands and clay to solid rock. This procedure solved the problem, and was Drake's only real contribution to petroleum technology.

On Saturday, August 28, 1859, the drill dropped into a 6-inch crevice, making the total depth of the well 69½ feet. Withdrawing the tools, Mr. Kier's former driller, William Smith, went home, intending to resume operations on the following Monday. But in examining the well on Sunday, "Uncle Billy," as he was called, saw a dark fluid in the hole. Plugging the end of a tin water spout he let it down with a string. When he drew out the spout it was full of oil! This was the humble prototype of the great modern oil wells.

The pump was at once adjusted, and the well commenced producing at the rate of about twenty-five barrels a day. The news spread like lightning. The village was wild with excitement; the country people round came pouring down to see the wonderful well.

Here again Mr. Bissell (as well as one of his partners, Mr. Jonathan Watson) showed his keen judgment; and Mr. Drake demonstrated his lack of understanding of the very product with which his name was to be inseparably linked.

Mr. Watson jumped on a horse and hurried straightway to secure a lease of the spring on the M'Clintock farm, near the mouth of the creek. Mr. Bissell, who had made arrangements to be informed of the result by telegraph, bought up all the Pennsylvania Rock Oil stock it was possible to get hold of, even securing much of that owned in New Haven, and four days afterward was at the well. His views of the matter had ever been the broadest, as his transactions had been the boldest.

While others were seeking for surface indications before leasing, he rushed forward, and secured farm after farm down the creek and along the Alleghany, where there were no surface indications whatever. The result has proven the wisdom of his conclusions. Drake unfortunately took a narrower view of the matter. He pumped his well in the complacent conviction that he had tapped the mine! He was probably led into this supposition by what seemed to him the remarkable incident of having struck a crevice. No money was paid on most of the leases taken at first; a royalty of an eighth or a quarter only being reserved by the easy old farmers who owned the land, and without a cent he might have secured any quantity of territory. He was repeatedly advised to do so by shrewd men who were themselves laying the foundation of fabulous fortunes; but it was his fatal misfortune to disregard that advice. When several other wells had been struck, and his eyes were opened to his mistake, it was too late, the golden opportunity had fled.

But by 1863, Drake, by acting as an oil commission merchant, and the Titusville justice of peace, had gathered together a fortune of about $16,000.

With this sum he entered the brokerage business in New York. In a few months he had lost it all. He came ill from a neuralgic affection of the spine, and returned to Titusville essentially as a beggar. The kind-hearted citizens at once raised $4,200 for the relief of himself and family. Finally, in recognition of his services to the state, the Pennsylvania legislature in 1873 granted him and his wife a pension of $1,500 a year.

In contrast to Drake's sad end, Bissell grew in wealth and importance. In 1864, he represented the oil dealers of Pennsylvania, and the Petroleum Board of New York, at Washington, where he successfully argued against taxation of crude oil before the Ways and Means Committee. He later became president or director of a number of large concerns. To his death he continued to maintain a powerful and beneficial interest in the industry which he had done so much to found.

I close this historical note on the early days of oil and gas production with a quotation which appears to refer to the modern epoch:

> The oil companies are, in turn, passing through an ordeal which will test their soundness. One result may be that of wiping out a number of them; another may be that of increasing the list. Three years ago the nation felt the shock of a universal rise of prices. It is now staggering under the greater shock of a universal fall. At what moment the cloud may actually burst it is impossible to say, nor how soon the skies may become commercially serene.

But this is history, too! The quotation, like the present paper, was written in April—but the year was 1865. Truly there is nothing new under the sun!

The oil and gas industry, the petroleum engineers and even the world at large should take courage from this unwarranted dirge from out of the past.

# RELATION OF EDUCATION TO THE SUCCESS OF EMINENT WOMEN

By BERTHA BEACH THARP

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In the past it was thought perfectly proper for an English-speaking woman to do housework, enjoy a garden and to indulge in the fine arts or to assist her husband in his work, but custom forbade her working outside of the home for wages. To-day, this customary way of looking at woman's work is gradually breaking down under social changes which can be traced to a movement stimulated by the doctrines and philosophies inspired by the French Revolution and given further impetus by the Industrial Revolution. Women are now enjoying greater freedom, socially, economically and politically, than they have in any other period of English history. As a result of this freedom, women are being permitted to enter practically any of the occupations or professions they desire.

Under modern conditions, women are no longer content with the routine duties of the home, as were their mothers and grandmothers, and are constantly in search of opportunities for broader development. Parents, too, are seeking information that will aid them in preparing their ambitious and capable daughters for a successful life. With this in mind, a statistical study pertaining to the education of eminent women was made with a view of finding what correlation, if any, exists between education and success.

In approaching the problem, the most practicable procedure was to analyze educational data pertaining to women who have achieved success in recent years. It was found that "Who's Who in America" offered the best source for the desired information; accordingly, one thousand women were selected at random from this publication for 1929, and data pertaining to their education were assembled.

The first step in the analysis of the data was the grouping of the women according to occupations or professions representing their major activities. This grouping indicated that the great majority of the eminent women were engaged in professional work, while only a small proportion had entered business or an occupation. The largest group, or about one third, were authors, while the second largest group, constituting about one fifth, were educators.

There is a fairly high correlation between education and the success gained by the women of this survey, judging from the fact that about 75 per cent. of them were credited with training in addition to that received in high school. About one half of the women attended a college or a university, while about one fourth received training in an academy, institute or normal school or had private training. In the case of 158 of the women, no reference was made to their education, except that they had been educated in the public schools. These findings indicate that the chances of gaining success were about twice as great for the women who had a college education as for those privately trained or educated in an academy, institute or a normal school.

The chances for women gaining success without college education were much more favorable at the beginning of this century, as is shown by the fact that 32.25 per cent. of the women listed in "Who's Who in America" for 1903

attended college or a university,[1] as compared with 51.5 per cent. of the one thousand women included in the 1929 publication. The difference between these percentages indicates an increasing correlation between education and success. This signifies that it will be more difficult for women of the future to win success without higher education, notwithstanding the fact that it is often contended that a generalization concerning the relationship of higher education to success is of little value, since achievement is dependent upon both nature and nurture.

Even though there is a difference of opinion as to the weight that should be given to formal training as a factor in the achievement of success, few would deny that the mind is more quickly orientated to the vast accumulation of human knowledge by means of a college experience. These same women might have become prominent through their precocity and ambition without formal training, yet it seems reasonable to believe that their talents would be brought to fruition more quickly and effectively by institutional training than if left entirely to their individual efforts. This is, of course, a proposition which does not admit of positive proof.

It is of interest to note that Professor Dexter concluded from his survey made in 1903 that the correlation between education and achievement of success was not as great for women as it was for men.[2] The lower correlation, as explained by Professor Dexter, might be the result of a lower standard of eminence for women than for men. But granting there is truth in this explanation, it is reasonable to believe that the standard of eminence for women will become greater, since higher education is becoming more prevalent among women. According to the following data taken from the "Biennial Survey of Education" the number of college women is increasing rapidly.[3]

TABLE I

| | 1910 | 1928 | 1930 |
|---|---|---|---|
| Number of women enrolled in colleges and professional schools | 104,701 | 356,137 | ........ |
| Number of baccalaureate degrees conferred upon women | 7,420 | 37,153 | ........ |
| Number of graduate degrees conferred upon women | 602 | 4,858 | ........ |
| Number of females in U. S.* | 44,639,989 | ........ | 60,637,966 |

* United States Statistical Abstract, 1929 and 1930.

While the great increase in the number of college women in our country is chiefly the result of economic pressure, leisure and a popular desire for learning are influencing factors. In response to the wide demand for education among women, many state coeducational institutions of higher education have been established, and knowledge obtained by all classes of women has been increased far beyond that of any other age.

It will be of interest to young women who are weighing the value of an education to know that in less than thirty years the correlation between success and education has become greater in ten of the professions listed in this study. According to a comparison of data of this survey with those of a similar one made in 1904, there has been a notable increase in the proportion of women having a college education among the physicians, social workers and journalists, as is shown in Table II. There was,

1 "Who's Who in America," 1903, p. xix.

2 "A Study of Twentieth Century Success," *Popular Science Monthly*, lxi, May–October, 1902, p. 251.

3 U. S. Department of Interior, Bulletin No. 16, 1930, p. 698.

also, a substantial increase among the missionaries, authors, educators and scientific women. The increase in the proportion of college-trained women among the artists, actresses and musicians is significant, although smaller than for the other professions.

TABLE II
PROPORTION OF EMINENT WOMEN ATTENDING COLLEGE, 1904 AND 1929 SURVEYS[4]

| Occupational and professional groups | Attended college (per cent.) 1904 | Attended college (per cent.) 1929 | Increase in proportion |
|---|---|---|---|
| Authors | 12.70 | 46.58 | 33.88 |
| Artists | 2.90 | 20.00 | 17.10 |
| Educators | 46.00 | 76.11 | 30.11 |
| Journalists | 18.50 | 60.46 | 41.96 |
| Actresses | 1.70 | 19.40 | 17.70 |
| Musicians | 2.30 | 19.73 | 17.43 |
| Social workers | 14.40 | 54.68 | 60.28 |
| Physicians | 33.33 | 100.00 | 66.66 |
| Scientific women | 41.00 | 70.27 | 29.27 |
| Missionaries | 58.50 | 72.72 | 34.20 |
| Librarians | ?? | 85.18 | ........ |
| Lawyers | ? | 100.00 | ........ |

The relation between success and college training was greater in certain fields of activity than in others. There is an exact correlation in case of the lawyers and physicians; and since 76.11 per cent. of the educators attended college and 70.27 per cent. of the scientific women, 72.72 per cent. of the missionaries and 85.15 per cent. of the librarians received higher education, there is a fairly close correlation in these cases. The correlation between success and higher education for the artists, actresses and musicians is comparatively low, but the relation in case of the social workers, politicians and authors would indicate that the women without a college education had as many chances of gaining success as did those with college training.

The taking of a graduate degree does not appear to have increased the chances of success, since as many women gained eminence with only a baccalaureate degree as did with a graduate degree. Of the 412 women who earned college degrees, 198 received baccalaureate degrees, while 214 took degrees representing more than four years of study. The number earning graduate degrees was slightly less than 214, since it was not possible in a few cases to distinguish earned from honorary degrees. The data show that only a small percentage of the authors, artists and musicians were credited with postgraduate work, while about half of the educators and scientific women received credit for advanced work. About one fourth of the journalists and one third of the librarians earned graduate degrees.

Four of the high correlations between success and college preparation were accompanied by low percentages of marriage, as is shown in Table III. About 50 per cent. or less of the lawyers, physicians, educators and librarians were married, while 76 per cent. or over in each group attended college. Quite the reverse took place among the artists, actresses and musicians. Over 50 per cent. of the women of each of these groups were married, while less than 20 per cent. were college trained. The librarians showed the lowest correlation between marriage and college education. The difference in correlation was not particularly great for each of the following groups—authors, journalists, missionaries, politicians and social workers. These data support the theory that education discourages marriage.

Data were compiled to show the ages at which the women of this survey were graduated. Although it was not possible to ascertain the ages of the entire group, a sufficient number were found to give a fair idea. The ages of graduation for the sample group ranged from sixteen to fifty-one years. In the field of art, 70 per cent. of the degrees were

[4] Amanda Carolyn Northrop, "Successful Women of America," *Popular Science Monthly*, lxiv, 1903–1904, p. 237.

TABLE III
PER CENT. DISTRIBUTION OF EMINENT WOMEN WHO ATTENDED COLLEGE AND WHO MARRIED, 1929 DATA

| Occupational and professional groups | Per cent. of women married | Per cent. of women who attended college |
|---|---|---|
| Physicians | 38.00 | 100.00 |
| Lawyers | 50.00 | 100.00 |
| Librarians | 22.22 | 85.18 |
| Educators | 35.84 | 76.11 |
| Missionaries | 54.54 | 72.72 |
| Scientific women | 48.64 | 70.27 |
| Miscellaneous | 60.00 | 70.00 |
| Journalists | 55.81 | 60.46 |
| Social workers | 75.00 | 54.68 |
| Politicians | 68.75 | 50.00 |
| Authors | 59.90 | 46.58 |
| Artists | 51.00 | 20.00 |
| Musicians | 67.10 | 19.73 |
| Actresses | 64.17 | 19.40 |

received on or before the twenty-third year, while in the field of science 56 per cent. were earned within this age range. No degree in science was taken earlier than the eighteenth year, while several degrees in art were received before this age. These data show a tendency for the degree in science to be taken at a more mature age than the degree of art, which result may be explained in part by a few of the women taking two degrees. When this occurred, the bachelor of art degree was usually taken first and the bachelor of science second.

The ages at which the master's degree was earned ranged from twenty to fifty-one years. About one third of the women whose ages were given took this degree on or before the age of twenty-five, while the remainder took the degree after that age. In the majority of cases a period of two or more years intervened between the time of taking the undergraduate and the graduate degree. Doing graduate work at a more mature age might very well be a factor which added to the superior preparation of the eminent women. Professor Thorndike, of Columbia University, has expressed the view that we err in considering early learning as a law of nature and as being invariably superior.

Since 258, or about one fourth, of the women of this study spent some time abroad, it is evident that there is a correlation between success and travel. Professor Ellis concluded from his study of "British Genius" that travel played an important rôle in the achievement of success.[5] The present study shows that 61 per cent. of the artists and 44.73 per cent. of the musicians spent some time in foreign countries. Only 28.80 per cent. of the educators traveled abroad; the proportion of those traveling or studying in other countries varied among the remaining groups from 24.32 per cent. of the scientific women to as low as 4.76 per cent. of the physicians.

It will be of interest to those who differ in opinion concerning the value of training women receive in coeducational institutions and that received in women's colleges to learn that 70, or 13.59 per cent., of the 515 college women enrolled in colleges exclusively for women; 100, or 19.41 per cent., attended women's colleges and coeducational colleges, while the remaining 345, or about 67 per cent., received their training in coeducational institutions. This means that only a small percentage of the college women were educated in institutions where men instructors did not predominate.

The proportion of eminent women who attended five of the large private colleges for women has practically doubled since a similar study was made in 1904.[6] Data in Table IV show that 51, or 5.34 per cent., of the women of the 1904 study attended either Bryn Mawr, Vassar, Smith, Radcliffe or Wellesley as compared with 134, or 13.4 per cent., of those included in the 1929 sur-

[5] Havelock Ellis, "British Genius," *Popular Science Monthly*, lviii, 1900–1901, pp. 59–67.

[6] Amanda Carolyn Northrop, "Successful Women of America," *Popular Science Monthly*, lxiv, 1903–1904, p. 237.

TABLE IV
NUMBER AND PERCENTAGE OF EMINENT WOMEN ATTENDING SELECTED WOMEN'S COLLEGES, 1904 AND 1929 SURVEYS

| Name of college | 1904 Survey* | | 1929 Survey | |
|---|---|---|---|---|
| | Number attending | Per cent. attending | Number attending | Per cent. attending |
| Vassar | 19 | 1.99 | 33 | 3.3 |
| Wellesley | 13 | 1.35 | 32 | 3.2 |
| Smith | 8 | .83 | 31 | 3.1 |
| Radcliffe | 7 | .73 | 19 | 1.9 |
| Bryn Mawr | 4 | .41 | 19 | 1.9 |
| Total† | 51 | 5.34 | 134 | 13.4 |

* Amanda Carolyn Northrop, *op. cit.*, Vol. lxiv, p. 241.

† Total number in 1929 Survey, 1,000; total number in 1904 Survey, 954.

vey. This increase, however, must be attributed in part to the fact that the proportion of women attending both private and coeducational colleges increased greatly during the same period.

To throw additional light on the educational background of these eminent women, it was thought worth while to assemble data pertaining to the sororities and the honorary organizations to which these women were elected, since membership in these societies is in a measure indicative of the social inclinations and scholarship of the women. Of the college graduates 28, or 6.79 per cent., were members of professional organizations, and 79, or 19.17 per cent., were elected to honorary societies noted for high scholarship. The majority, or 71, of those elected to honorary organizations were members of Phi Beta Kappa.

### GENERAL SUMMARY AND CONCLUSIONS

It is very probable that the general results of this study could have been reached by reasoning and observing, but it is believed that conclusions carry more weight when backed by statistical data.

The evidence developed in this study shows that the proportion of women attending college has increased considerably among the women of "Who's Who in America" since the early part of the present century. The analysis supports the view that women trained in colleges have greater chances of gaining prominence than do women trained in institutions of less than college rank; however, data show that there is a higher correlation between college training and success in certain fields of activity than in others. The conclusion is that a college education is of less importance to the artist, actress and the musician than it is to the women in the other groups. It appears from the study that travel was an important part in the lives of the artist, actress and musician, but played a less important rôle among the women in other fields of work. Contrary to what might be expected, the findings show that among the college graduates the chances for success were as great for those who did no graduate work as for those who pursued advanced courses; nevertheless, the correlation between graduate work and success was greater in a few professions than in the others.

There is support in the study for the view that education necessary for success in certain professions means, in a measure, a sacrifice of marriage.

In general, the study shows a trend for education to play an increasingly important rôle in the gaining of success by women, and leaves the impression that women of the future will find it more and more difficult to compete for a place among the eminently successful without a thorough college training as a background for their work.

# THE USE OF THE EXPERIMENTAL METHOD IN THE STUDY OF HUMAN PARASITIC INFECTIONS

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## Introduction

The earliest studies on parasitic infections and the diseases which they produce were observational and analytical in character. As early as 2,300 years before the Christian era the Chinese recognized the three species of malaria plasmodia on the basis of the types of fever which they produced. They also observed that malarial fevers or ague were associated with "spleen cake" or enlargement of the spleen. Later the Greeks and Romans not only differentiated the three kinds of malarial infections by the febrile reactions which they produced, but also associated their occurrence with swamps. However, it was not until the middle of the nineteenth century A.D. that any one suggested the possible relationship of mosquitoes or other insects to the transmission of this disease. The Medina or Guinea worm, *Dracunculus medinensis*, was well known in the days of Moses; he instructed the Children of Israel how to twist this "fiery serpent" of the wilderness out of their skin onto a rod or stick, but he had no idea that the infection was initiated in man by swallowing a crustacean animalcule, Cyclops, in raw drinking water.

The Egyptians of the sixteenth century B. C. probably recognized Ascaris, the hookworms and tapeworms; the Greeks referred to tapeworms and hydatid, and the Arabian physician, Avicenna, who lived during the tenth century of our era, wrote on tapeworms, Ascaris, hookworms and the pinworm or seatworm (*Enterobius vermicularis*) and methods of expelling these worms from the body. After the Middle Ages physicians and workers in the natural sciences began to discover and classify various worms, visible to the naked eye, commonly found in man and domestic animals. Because they employed only external characters of the worms for purposes of differentiation they confused flukes (trematodes) with leeches and failed to realize that tapeworms and bladder worms were separate phases of the same life cycles. With the advent of the microscope the internal anatomy of the larger parasites (the worms) was studied and tremendous numbers of these organisms were described. This led to the erection of a huge system of artificial classification which is to-day possibly the greatest "white elephant" in attempts to elucidate the life cycles of these organisms. While the speaker does not wish to belittle the careful descriptions of parasites made by investigators of the past century, and realizes that these studies have been the foundation for all subsequent serious biological work on the subject, it is certainly true that the morphologist and the systematist by their shortsightedness have frequently kept the doors closed to the bigger, more vital sphere of experimental inquiry into the realm of parasitic infections.

Among the earliest helminthologists to realize the value of experimentation were Kückenmeister, who in 1852 and 1854 demonstrated that bladder worms were larval stages of tapeworms, and Leuckart, who with Virchow in 1854 elucidated

the life cycle of the trichina worm (*Trichinella spiralis*). Later (in 1882) Leuckart experimentally proved the relationship of the several stages in the life cycle of the sheep liver fluke (*Fasciola hepatica*), and in the same year demonstrated the successive stages in the development of the diminutive intestinal nematode parasite of man, *Strongyloides stercoralis.* Meanwhile, Fedschenko (1869) had incriminated Cyclops in the transmission of the Medina worm, and Patrick Manson (1878–1879) had shown that a culicine mosquito was involved in the transmission of Bancroft's filarial infection. With this latter discovery the modern epoch in experimental investigation may be said to have gotten under way, for it was due to this discovery that Manson conceived the idea of the mosquito transmission of malaria, which was successfully demonstrated by Ronald Ross and by Italian scientific men just as the nineteenth century came to a close. One must not forget, however, that the involvement of the cattle tick (*Boophilus annulatus*) as the intermediate host of Texas cattle fever (*piroplasmosis*) by Smith and Kilbourne in 1892–1893 constituted both a landmark and an inspiration for all subsequent workers in the arthropod transmission of disease. Furthermore, the elaborate demonstrations by Arthur Looss at the beginning of the present century (1905–1911) of the life cycle of the hookworm and its route of migration through the human body served as a masterpiece for all subsequent studies in helminthology.

The first accurate description of a pathogenic protozoan parasite was that of Lösch (1875), who discovered the pathogenic ameba (*Endamoeba histolytica*), described the associated symptoms and pathology, and in the course of his studies inoculated dogs with the infective organism. This was the first experimental work in parasitic protozoology.

### Significant Advances in Human Parasitology Based on the Experimental Method

It now seems appropriate to review in brief a few of the significant developments of parasitology due to the use of the experimental method.

(1) *Amebiasis.* Following the initial work of Lösch (1875) in the use of the dog as an experimental host for the pathogenic ameba (*E. histolytica*) Kartulis (1885–1891), Kruse and Pasquale (1894), Hlava (1887) and Harris (1901) all used experimental animals, including dogs, cats, jumping mice, guineapigs and rabbits, in attempts to elucidate the life cycle of the organism. It remained for Walker and Sellards (1913) by the use of human volunteers to show that free-living amebae and *Endamoeba coli* were non-pathogenic and that amebic enteritis, including dysentery, developed in a high percentage of individuals inoculated by mouth with ripe cysts of *Endamoeba histolytica.* The later experimental work of Kessel (1928) on kittens and pigs, of Dobell (1931) on monkeys and kittens, of Hegner and his colleagues (1932) on monkeys and of the writer (1930–1932) on dogs has done much to elucidate the method by which infection is initiated, the lytic action of the organism and the lesion which it develops. These investigations have also served to demonstrate that all strains of *E. histolytica* are potentially pathogenic, but that infected individuals may at any one time have symptoms of dysentery, chronic enteritis, vague intestinal or systematic symptoms or may be symptomless carriers.

Very important in the development of our knowledge of this organism has been its cultivation in the test-tube, which was first announced by Boeck and Drbohlav in 1925. This technique initiated studies on encystation and excystation and the nuclear divisions at the time of and subsequent to excystation [Yorke and Adams (1926), Dobell (1925,

1928)]. Furthermore, Cleveland and Sanders (1930) have also obtained bacteria-free cultures of organisms but have apparently shown that the ameba will not propagate in the test-tube in the absence of certain bacteria. Finally, Craig (1928, 1931), by demonstrating the systematic reaction to *E. histolytica,* in the form of antigenic substance in the blood serum, has developed a highly successful method for determining the presence of the organism in the bowel and for following the reaction of the body to the organism.

(2) *Malaria.* It has already been stated that the inspiration for the epochal discovery of Ross was the work of Manson and Manson's hypothesis of the mosquito transmission of this disease. Ross as a young army surgeon in the face of almost insuperable obstacles successfully demonstrated that the mosquito was the intermediate host and transmitter of this parasite. After three years of partial success (1895–1897) with the estivo-autumnal human infection Ross was transferred to a non-malarious area, but studied the development of another plasmodium in birds and succeeded in transmitting it from naturally infected birds through the mosquito to parasite-free birds (1898). The complete development of the human malaria parasites was demonstrated in Italy by Bastianelli, Bignami and Grassi in 1898 and by Manson in London in 1900. That protection from malaria is provided by screening from anopheline (dapple-winged) mosquitoes was first shown by Low, Sambon and Terzi in the year 1900 in an experimental hut set up in Italy at the suggestion of Manson.

With the acceptance of the mosquito-transmission of malaria, work was initiated in various parts of the world where malaria is rife, to determine the anopheline mosquito hosts of the infection, both in nature and in controlled laboratory tests. In this way several dozen species of the genus Anopheles have been incriminated. It has been found, however, that all species capable of transmitting malaria in the laboratory are not necessarily equally important under natural conditions, and that a dangerous mosquito host in one country, as, for example, *Anopheles ludlowi* in the Federated Malay States, may not be similarly important in the Philippines, where it also abounds. Here in our own area there are four or five anophelines, but only one, *Anopheles quadrimaculatus,* is responsible for malaria as a wide-spread infection in the South.

The introduction of the malaria plasmodium as a therapeutic agent in paresis by Wagner von Jauregg (1924) has opened an extremely important field for experimental study of the effects of the organism in the human body under controlled conditions, so that it is now possible to observe the development of the infection from the time of inoculation until the infection is naturally controlled or until chemotherapy is instituted. The studies of James (1926–1927) in England and of Boyd (1932) in Florida, in rearing anophelines, infecting them with known strains of malaria and later inoculating non-immune paretics, has filled in many of the gaps in our knowledge of the interrelationship of parasite and hosts.

Working along other lines Clark (1929, 1930) in Panama and recently Knowles (1932) in India have studied malaria in monkeys. Knowles has found a monkey type of malaria which is fatal to a certain species of monkey, apparently symptomless in another monkey and produces marked symptoms in human volunteers. In one host it is morphologically similar to the human tertian malaria plasmodium, in another, to the human quartan malaria species and in still a third has some of the characters of the estivo-autumnal parasite.

This study has just been announced but promises remarkable opportunity for undertaking investigations on host-parasite relations. Growing out of Clark's work (*vida supra*), Taliaferro (1932) has studied the host-tissue reaction in monkey malaria and has demonstrated experimentally much that has been surmised but never proved in human infections.

On the therapeutic side within the past fifteen years tremendous efforts have been employed to develop experimentally satisfactory substitutes for quinine. Out of the hundreds of synthetic compounds studied plasmochin and recently atebrin have been found to give promise of definite use.

In the field of malaria control, aside from therapeutic prophylaxis, intensive experiments have been made in attempts to prevent the breeding of malaria mosquitoes. The introduction of the little fish Gambusia and the water-weed Chara into mosquito-breeding waters have been natural experiments of no small merit. Oiling of the breeding places and dusting with Paris green have required infinite study to determine the most suitable materials, the best technique and the practicability of each method.

Thus malaria, the greatest scourge of mankind, has tested the ability of the greatest men of our times. Accomplishments in this field have been almost exclusively experimental in character.

(3) *Trypanosomes.* The discovery of the trypanosomes in Africa, first in cattle by Bruce (1895), then in man by Forde (1901, *Trypanosoma gambiense*) and by Stephens and Fantham (1910, *T. rhodesiense*) opened the way for demonstration of the tsetse flies as intermediate hosts and transmitters of these infections (Kleine, 1909; Kinghorn and Yorke, 1912). The two human species morphologically indistinguishable in man, have been shown by murine inoculation to be differentiable in this experimental host. Meanwhile Chagas (1909) showed that South American trypanosomiasis was transmitted by a reduviid bug, *Triatoma megista.* The investigations of Dr. Louise Pearce on the trypanosomicidal properties of an arsenical preparation, tryparsamide, first in rats and later in human cases, might conceivably be taken from a modern Arabian night's tale, were it not known as fact.

(4) *Rickettsial infections.* We are all more or less familiar with the sacrifices of life that have been made to typhus fever, with its tremendously high mortality. Not till 1909 did the distinguished French investigator, Charles Nicolle, demonstrate that body lice played a rôle in the transmission of this infection. Another rickettsial infection with high mortality, Rocky Mountain spotted fever of our own Northwest, was shown by Ricketts (1906) to be transmitted by a tick, *Dermacentor andersoni.* Recently Parker, of the U. S. Public Health Service, has developed a vaccine which affords relative protection from this dread disease. In far-off Japan a serious fever which broke out in the lower river valleys in springtime was first described by Baelz in 1879. Believed by the country folk to be associated with a little red mite, *Trombicula akamushi,* experimental work on rodents and monkeys has amply demonstrated this hypothesis, while Nagayo (1931, 1932) has shown that the organism belongs to the Rickettsia group. Pseudotyphus of Sumatra has also been found to be transmitted by a red mite, while Brill's disease and endemic typhus in the United States have just recently been found to be disseminated by rat-borne arthropods (mites and fleas).

(5) *Yellow fever.* Who of us is not familiar with the experimental studies on yellow fever in Havana by Reed, Carroll, Agramonte and Lazear (1900) and

the proof that the tiger mosquito was responsible for this plague of all our Southern ports? With their proof in hand Havana, the Canal Zone, New Orleans, Mobile and Charleston were made safe for human existence. The recent work of Stokes and his associates (1928 *et seq.*) in demonstrating the susceptibility of the macaque to this infection has made it possible to study the virus of this disease and to prepare a vaccine which is at least partial protection for non-immune human beings.

(6) *Hookworm infection.* Probably next to malaria hookworm disease is the most wide-spread parasitic infection that has caused the death of untold millions and has been responsible for incalculable social and economic loss. The discovery of the worm by Dubini in 1838 was followed by significant findings by Grassi in 1878, Perroncito in 1880 and Leichtenstern in 1886–1887. These led by orderly sequence to the experimental studies of Looss, initiated in 1896 and concluded in 1911, which provided us with a complete story of the development of this worm parasitic in the human body and free-living in the soil, and the method of human inoculation through the skin. Looss used dogs primarily for his experimental studies, but submitted to infection himself, in order that he might have more intimate knowledge of his problem. Following the development of a simple apparatus by the Dutch investigator, Baermann (1917), for isolating the hookworm larvae from the soil, Cort and his students (1921) began an extensive investigation in the laboratory and in the field to determine the bionomics of the hookworm. It is now possible by egg-count methods to estimate the worm-burden in an infected human being. The development of the free-living stages under different conditions of soil, moisture and temperature is now known. It has also been discovered that animals on a deficient diet are most susceptible to infection (Foster and Cort, 1932) and that animals on a balanced diet gradually acquire an immunity to the infection, so that reinfection becomes more and more difficult. Creeping eruption, a skin infection common in Florida and extending throughout the Gulf Coast, has been found to be due to a hookworm, *Ancylostoma braziliense,* which commonly infects dogs and cats along our Southern shores but is less adapted to man as an intestinal infection.

In the development of drugs for the eradication of hookworms carbon tetrachloride was first advocated by Hall and his colleagues (1921) as a good anthelmintic for dogs. Human trial was initiated by Leach (1922) on condemned prisoners in Ceylon. With the extensive use of this potent vermifuge a few fatalities resulted from its administration. Lamson and Minot (1928) have shown that this, like eclampsia, is due to histamine poisoning when there is an inadequate supply of calcium in the blood. The more recent introduction of tetrachlorethylene and hexylresorcinol as hookworm therapeutics in human medicine has been preceded by careful pharmacologic studies on dogs and other laboratory animals.

(7) *Ascaris lumbricoides.* The common roundworm of children has been known since ancient times. Only within the past twenty years, however, has its life history been revealed. Thanks to the experimental work of Stewart (1916) and of Ransom and Foster (1917) and Ransom and Cram (1921), we now have proof that the ripe egg, when swallowed, hatches in the duodenum, and that the emerging larva penetrates the intestinal wall to the mesenteric blood vessels or lymphatics, is carried through the right heart to the lungs and works its way out of the capillaries into the air passages, is carried up to the epiglottis, migrates down the

esophagus and finally within the small intestine develops to the adult stage. The lung symptoms, during the passage of the larvae through this organ, were definitely corroborated by two Japanese volunteers who submitted themselves to experimental infection (1922) and at the appropriate time developed a typical "Ascaris-pneumonia." Recently Cort and Otto (1929 *et seq.*) have carried out extensive epidemiological studies on Ascaris, comparable to the earlier hookworms investigation of Cort and his students. These have shown how and why the infection is essentially one of childhood, since the ground around unsanitated homes is seeded with developing eggs which are passed in the stools of infected children. The pharmacological studies of Lamson (1931) on the specific vermicidal properties of hexylresorcinol for Ascaris infection constitute one of the recent contributions to experimental therapy.

(8) *Strongyloides.* The minute nematode, *Strongyloides stercoralis,* which parasitizes the tissues of the upper intestinal tract, is another example of a parasite for which information has been acquired by the experimental method. Discovered by Normand in 1876 and described by Bavay in the same year, the worm was shown by Leuckart (1882) to have both a parasitic and a free-living phase. At times the free-living phase was short, as in the hookworm; at other times a complete reproductive cycle developed outside the body. Extensive experimental work of Fülleborn (1914) and by Sandground (1926) has elucidated the migration route through the blood stream and lungs and has indicated that climate is not entirely responsible for the extent or type of the free-living phase (whether direct or indirect in mode of development). Recent work of the writer and his associates (1931 *et seq.*) has demonstrated for the first time the parasitic male, which apparently fertilizes the parasitic female and then dies or is passed in the stool. A hyperinfective mode of development has also been observed, wherein the larvae by a telescoped type of development mature to the infective stage before passing out of the bowel and are capable of producing a hyperinfection of the patient. The speaker has also experimentally confirmed and elaborated the work of Sandground in showing the instability of types of development and their mutability from one type into another, especially from the indirect and hyperinfective types into the direct type.

(9) *Filarial worms.* From 1875 when Manson found larvae of Bancroft's filaria circulating in human peripheral blood at night, the life history of this worm and its clinical manifestations have been a puzzling complex of fact and theory. Except for the transmission of this worm from man to man by the bite of certain mosquitoes which serve as intermediate hosts little is even now understood of its relationship to its human host. Within recent years the transmission of other human filarial worms, including the loa worm (*Loa loa*), the persistent filarial worm (*Acanthocheilonema perstans*) and the convoluted worms (*Onchocerca volvulus* and *O. caecutiens*), has been shown to take place through the bites of blood-sucking flies. The studies of Strong (1930–1932) and of Hoffmann (1930, 1931) on *Onchocerca caecutiens* have added the latest knowledge to this infection as it exists in Guatemala and in Southern Mexico.

(10) *Tapeworms.* Certain of the human tapeworm life cycles were first demonstrated during the middle decades of the past century. Others were not completely elucidated until a few years ago. The life cycle of the broad fish tapeworm, *Diphyllobothrium latum*, was first fully demonstrated in 1917, although it had been known for many

years that infection by man was acquired by eating infested raw fish, and final confirmation of the hypothesis, that the dwarf tapeworm, *Hymenolepis nana*, requires no intermediate host, was not forthcoming until 1924.

(11) *Trematodes or flukes.* Reference has been made to the experimental demonstration of the life cycle of the sheep liver fluke by Leuckart in 1882 and independently by Thomas in 1883. For another quarter century no other fluke infection of economic importance to man was elucidated. Cumulative experimental data by Japanese investigators on the Oriental blood fluke, *Schistosoma japonicum*, culminated in the demonstration by Miyagawa in 1912–1913 of the route of migration of this worm through the human body and by Miyairi and Suzuki (1913–1914) of the extra-human phases of development of this worm. This was followed (1915) by Professor Leiper's demonstration of similar life cycles for *Schistosoma haematobium* and *Schistosoma mansoni* in Egypt. Meanwhile Japanese workers had shown that the liver fluke, *Clonorchis sinensis*, was acquired from eating raw fish and the lung fluke, *Paragonimus westermani*, from consuming uncooked crayfish and crabs. It remained for an American missionary physician in China, Dr. C. H. Barlow (1923, 1925) to elucidate the life cycle of the large intestinal fluke, *Fasciolopsis buski*. Having observed that patients suffering from this disease in his hospital came from a certain district, he went to the area in question and after careful investigation eliminated all probable sources of infection except two water plants (the water "chestnut" and the water caltrop), the products of which were commonly consumed raw. With this beginning he finally incriminated not only these plants but also certain snails which lived in intimate contact with the plants. Finally, to confirm his fully developed theory, that the larvae of this fluke encysted on the edible parts of the plants and were accidentally swallowed by human beings, he submitted himself to infection, and after three months was able to recover eggs of the parasite in his stool. Later the worms were recovered after administration of an anthelmintic, but not until marked toxic symptoms of the infection had developed.

### The Ethics of the Experimental Method

In most experimental work with human parasitic infections laboratory animals can be utilized for all practical experimental tests, thus obviating the need for and potential risk by human volunteers. Such laboratory animals should necessarily be treated with the greatest kindness and every effort should be made to avoid pain. One careful worker has stated that he always cared for his experimental animals himself, and even gave more thought and attention to their comfort and happiness than to his own health. If monkeys had been known to be susceptible to yellow fever and had been utilized by the Yellow Fever Commission in Havana (1900) unnecessary sacrifice of life would have been avoided. Yet in certain crucial types of experimentation it has been found highly desirable to know if human host-parasite relationships are directly parallel to those of susceptible experimental animals. Our knowledge of these infections is much richer and much surer by virtue of volunteer and, at times, accidental human infection. This is particularly true of amebiasis, trypanosomiasis, leishmaniasis, hookworm infections, ascariasis, tapeworm infections, Fasciolopsis infection and Dr. F. G. Cawston's accidental self-inoculation with the infective larvae of

the blood fluke, *Schistosoma haematobium.*

The experimental study of human parasitic infections, both in experimental animals and in the test-tube, is often fraught with imminent danger to the experimenter. Yellow fever, typhus, Rocky Mountain spotted fever, relapsing fever and tularemia are the most conspicuous examples of diseases in which some slip in experimental technique, known or unknown, has resulted in the death of the investigator. Fortunately, vaccines are now available at least as a partial protection against some of these infections, and others will undoubtedly be developed.

### Has the Experimental Method Outlived its Need in Parasitology?

It might seem from the foregoing enumeration of instance after instance, where important gaps in our theoretical and practical knowledge have been supplied by experimental demonstrations, that all the important problems dealing with human parasites have been solved. Possibly the most dramatic work has been accomplished, but much remains to be done. Among some of the unsolved problems the following will serve as examples.

I. The question of susceptibility or immunity to homologous or heterologous strains of the same parasite and to apparently physiologically different strains of the same organism.
II. The predilection of parasites for certain tissues of the body.
III. The problem of latency in malaria.
IV. Periodicity of the microfilariae in Bancroft's filarial infection.
V. The lung phase in hookworm, Ascaris and Strongyloides infection.
VI. Is *Endamoeba histolytica* always a tissue parasite? If so, why are 90 to 95 per cent. of infected individuals apparently symptomless carriers?
VII. Problems arising from the apparently spontaneous development of newly recognized diseases, such as Brill's disease and endemic typhus, and Rocky Mountain spotted fever in the Eastern United States.

No, the experimental method has not outlived its usefulness. Its utilization will be the means of supplying an increasing amount of valuable and necessary additions to human knowledge, with the consequent alleviation of suffering and distress.

# BIBLICAL BOTANY AND ARABIC LORE

By EPHRAIM HA-REUBENI

SECTION OF BIBLICAL BOTANY AND PLANT LORE, HEBREW UNIVERSITY, JERUSALEM

It must not be forgotten that the ancient Israelites, both the common folk and the teachers of the people, were a nation of husbandmen and herdsmen and made extensive use of plants not only for food and condiments, pasture for their cattle, for medicines, poison, laundry, dyeing and cosmetics, but for religious purposes on occasion of festivals and mourning. References to the plants growing on hills and in valleys of Palestine illustrated their folk-lore and parables. Flowers and trees gave their names to various places in the land and to the sons and daughters of the prophets and sages. In the course of their work in the vineyards and fields, and in valleys and on the seashore, at every season of the year, they observed many details of the various forms of the plants, and they learned to recognize and note their botanical development in different regions of the country. They even experimented in plant biology.

It is also imperative that intelligent inquiry be made into the Jewish and Arab plant lore of present-day Palestine and in neighboring countries. Such investigations can sometimes best be carried on in the tents of the Bedouins, in the herdsmen's booths and in humble fishing hamlets. In the course of many years' practical research on Biblical plants and plant lore, the importance of a close study of the plants of the Biblical and post-Biblical literature has therefore become increasingly clear in order to understand the words of the prophets and sages,—not merely for comprehending the bare text, but the ideas and emotions which swayed the prophets and the teachers of the people,—ideas frequently expressed by aid of the flora. Failure to appreciate the subtleties of botanical references is often the cause of distortion of the words of the prophets and results in the most erroneous explanations of the text. The plants in the Talmudic literature likewise are sometimes inaccurately described.

The great work of investigating the flora of Palestine, the plant lore of Palestine and neighboring countries and of the whole of ancient literature involves journeys into the fields and the valleys, into tents of the herdsmen, and again, turning from the fields and villages, to the many books published on the subject in Palestine and neighboring countries. Such investigations can not be carried out by scholars who come to Palestine for a limited period. Such work of necessity must actually be done in Palestine. It must be performed uninterruptedly for a period of many years.

An institution like the Hebrew University of Jerusalem, situated as it is, in the heart of Palestine, is peculiarly well equipped for this work. The section of Biblical plants and plant lore forms an important part of the work of the botanical department of the university. Attention must be drawn to the fact that the investigation of oriental plant lore is not only important as a help to understand ancient literature, but also as a study in itself, which must of necessity be of value as an aid in probing into the life of the orient, much less known to us than is supposed.

The study of the plants of Palestine from three points of view—Biblical, historical and botanical—may be termed "humanistic botany."

However, "humanistic botany" in Palestine, interesting in itself, must also serve through the Hebrew University the biological sciences in Palestine. The section of Biblical plants and plant lore of the young Hebrew University, not yet

fettered with the shackles of rigid tradition, is fostering the work of the section of Biblical plants and plant lore through research and through exhibitions which make the collections available to scientific men and to laymen. Exhibits of the plants are appropriately arranged in the museum, happily termed "The Museum of Plants of the Prophets and Sages and Plant Lore." The exhibits are arranged so that the plants and their component parts are preserved in their natural shape and color.

It is the only museum in the world where plants are shown in this manner. Mrs. Ephraim Ha-Reubeni, who has charge of this part of the work, has invented a series of new methods for such preparation of the material.

The artistic mounting of the plants in the museum in their natural shapes and colors is not only for beauty alone, but for the purpose of studying the morphology of plants and their parts in a minute and faithful manner. The labels giving explanations of the plants are arranged in Hebrew, Arabic and English, and in the course of time they will be printed in other languages also.

Many of the plants are arranged in their various forms of development from the time when they show their first petals until the blossoming and fruiting, and are exhibited so as to appear in their natural color and bloom.

In the plant lore branch of the museum is collected flora of the present day known to the Jews in Palestine, Syria and Iraq. A special hall has been set aside for Arab plant lore, which contains plants used for human food and fodder for cattle, various plants for industrial purposes, for medicinal purposes, poisons, fuel, for bird catching, fishing, graveyard plants and flora found in folk-lore and sayings.

To a great extent references to many matters in our ancient literature can be made more understandable by this collection of plants familiar to the native Jews and Arabs of our day. The ways of life of the people in Palestine and especially of the fellaheen and Bedouins, herdsmen and fishermen, have not altered materially from that of the Biblical and post-Biblical days.

In addition to lectures given at stated times in the university itself, requests are often received from both the botanical and historical point of view, from various parts of the country, from towns and settlements and especially from groups of workmen, for lectures on the plants found in their vicinity. These requests are fulfilled in so far as the means for such extension work by the department permit, and a number of addresses have been given, both for the Jewish colonists and their Arab neighbors, on the plants of the Bible and Talmudic times. One of the eventual hopes of the department is to arrange exhibitions of Palestinian flora which may be shown as traveling exhibitions in the countries of the Near East, perhaps even in Europe and America. The Hebrew University possesses the largest herbarium of Palestine plants in existence, and exchanges have already been effected with scientific institutions abroad of the first centuria in Palestine.

In addition to the work of research in this branch of botany, in which the writer has been engaged for the past twenty-five years, a popularization of the work has been attempted not only through exhibits in the Near East, Central Europe and the United States, but through collection of articles and drawings in realistic colors, with typical photographs.

A "Garden of the Prophets," in which an attempt will be made to show all plants and trees mentioned in the Bible and Talmud, is part of the plan of the Hebrew University to develop this side of its botanical work.

# SURFACE TENSION

By Professor W. C. HAWTHORNE
CRANE JUNIOR COLLEGE, CHICAGO, ILLINOIS

WHO of us have not enjoyed with our children the delightful adventures of Alice in Wonderland? And of all these, which is more amusing than the tale of the magic cakes which had the power of changing her size? I have often wished that our delightful spinner of tales had kept her of diminutive size for a little while, and given an account of her probable adventures. Many of them would have been all but unbelievable, while yet the author remained strictly within the bounds of sober scientific fact.

·For instance, if she had shrunk down to a height of two inches, she would have had no end of trouble in getting a drink from any cup of commensurate size, say one sixteenth of an inch in diameter. Such a cup could not be filled with water. When she dipped it below the surface, the water would simply stretch over the top, like a rubber membrane, and refuse to enter. Or, the cup once filled by some means or other, the water would refuse to run out.

Were she to become a little smaller, she would be able to walk over the surface of this same strange liquid dry-shod. Perhaps it would be safest to wear snowshoes and, provided they were dry when she stepped out on her stroll, she would be in little danger. Once let the shoes get wet, however, and she would be lost. It would be as difficult to break through the surface from below as from above, and however good a swimmer she might be ordinarily, she would find the same surface dragging on her every movement as if she were swimming through the thickest morasses. However, underwater swimming would present no difficulty. It would be only when she came up for air that the drag would be noticeable.

Put in this way, these properties of a liquid surface seem only an amusing fancy, but it is a question of life or death to myriads of the tiny creatures that swarm beneath our feet. Grasshoppers get their "drinks" from the dewdrops on the stems of plants; they dare not (at least do not) sip from the edge of a pool. Were they to do so and fall in, their fate would be sealed, and the same is probably true of other insects. Baby mosquitoes stick up their "tails" through this (to them) rubbery surface layer, open out a few hairs and hang there as safely as the oriole hangs in her swaying nest, with the advantage, of course, that they can let go and scuttle to safety at any instant, and the disadvantage that when the health officer comes along and spreads a thin film of oil over the water surface its strength is not able to support them and they perish for lack of air.

You may satisfy yourself as to the existence of this strong surface film by laying a dry needle carefully on the surface of water. Being of steel, heavier than water, it ought to sink; but it does not. On the contrary, you will notice that the water surface is depressed below it, forming a little cradle, so to speak, in which the needle floats. The witches who went to sea in a sieve depended on this property, as you may prove for yourself with a little boat made of wire gauze. Each wire will behave as did the needle, and the film stretching from one to the other will support a considerable weight. But—make sure the boat is dry. To make sure that

it will stay dry, best dip it in melted paraffin, shaking the surplus wax from the wires before it cools, but leaving a thin coating over each wire. Such a boat will not only float, but in it considerable water may be carried safely, provided that the film retains its continuity, like a thin membrane stretched over the wires. Let it be broken, *i.e.*, let the wires themselves get wet, and the magic property is gone. A loosely woven coat is impervious to any ordinary shower because of the water film formed on the surface, stretching from one fiber to the next. So, too, it is not the cloth of the tent that keeps out the rain but the film covering the interstices. If this film be broken, say by touching the surface from the under side, a leak promptly develops. The water-shedding power of the tent may be improved by "painting" it with a solution of paraffin in gasoline. This does not stop up the holes, but leaves a thin coating of wax over the individual fibers. Then they do not become wet, as they otherwise would in time and no longer support the film.

Here is another apparently unrelated phenomenon that really depends upon these unsuspected forces resident in the surface of liquids. The lower end of a piece of porous material, such as loosely woven cotton cloth, is allowed to dip into water. Soon the entire cloth is wet, and a surprising amount of water will rise through it in a short time.

Once again, who would imagine that "pouring oil on troubled waters," a device still used by mariners for smoothing out dangerous waves, and the manufacture of shot also depend on the same property of liquid surfaces as these other phenomena mentioned? Shall we look into the philosophy of the problem a little?

### Cohesive Forces in Liquids

It is very evident that forces are at play within a liquid which we ordinarily think nothing of. We have no trouble in recognizing and measuring cohesive forces in solids; they are not so evident in liquids; in fact, "as weak as water" is proverbial. But the forces are there, of surprising magnitude when we come to measure them—forces which pull the molecules together into as small a space as possible, and that of course is a sphere. To make shot, the melted lead is poured from the top of a high tower. It breaks up into perfectly spherical drops which fall into a tub of cold water and solidify before they have a chance to become distorted. A raindrop is spherical because every one of the billions of molecules constituting it is trying to get as near as possible to every other molecule. The same amount of water at rest is pulled out of shape by the force of gravity and the attractive forces between the molecules of water and the surface on which they lie. If the surface is not wet by the liquid, quite large drops may assume the normal shape of a liquid—spherical—as may be shown by drops of mercury or even of water on a dusty surface.

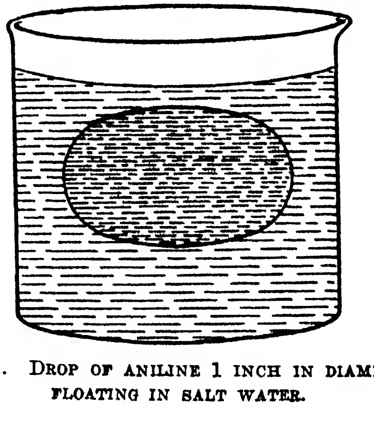


Fig. 1. Drop of aniline 1 inch in diameter floating in salt water.

Whenever a liquid is relieved from the distorting influence of other forces, so that it is not pulled out of shape by its weight, it takes this spherical form. Here is a large drop of aniline in a vessel of salt water of equal density, and you see the same tendency at work here.

### Measurement of Liquid Cohesion

When we attempt to measure those attractive forces directly, we encounter many difficulties. This has been one method: A long barometer tube has been carefully cleaned with sulfuric acid, then filled with mercury which has been boiled to drive out the air. Now when this is inverted, with the open end below the surface of mercury in a dish, we expect the column to fall to a height of thirty inches or less, this being the height of the barometric column sustained by air pressure. But Professor Osbourne Reynolds found that twice this height was sustained even when an air pump was applied to the lower end of the tube and the pressure there was exhausted to a very low amount. The sulfuric acid stuck to the upper end of the tube and the mercury to the sulfuric acid, and the rest of the mercury simply hung from the upper end like a chain of weights, indicating a minimum tensile strength of thirty pounds per square inch. Whenever a break did occur, it was because of a tiny bubble of air, which had the same effect as a nick in the edge of a ribbon under a strain. The break started there. Other methods have shown that the internal stress in a liquid must be reckoned as many times greater than indicated here.

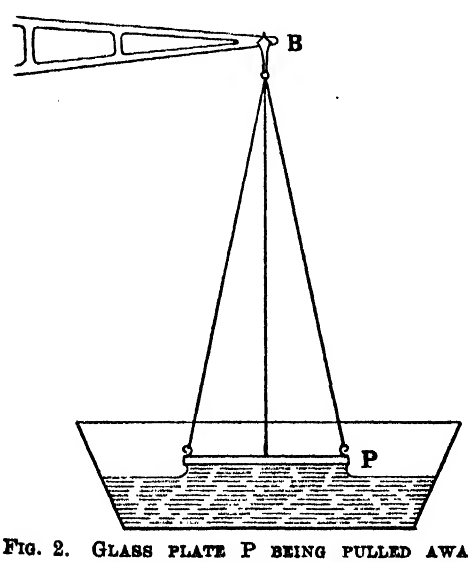



Fig. 2. Glass plate P being pulled away from water by balance B.

For water, we can easily prove the existence of such a stress by allowing a flat disk of glass, suspended from a spring balance, to touch the surface. The under part of the glass must be well cleaned with soap, then nitric acid and finally pure water. We shall see that a considerable force is required to pull the disk from the water, and since a film of water adheres to the surface of the glass it is plain that we have not overcome adhesion between glass and water, but cohesion between molecules of water.

### Sphere of Influence

Supposing that there is an attraction between the molecules of a liquid, even if nothing but the well-accepted force of gravity, it must fall off rapidly with distance; at least, inversely as the square of the distance, and many investigators think it may vary as the 4th power of the distance. Granting this, it is evident that an imaginary sphere could be drawn around every molecule, outside of which this force is practically nil. This is called the sphere of influence of that molecule, and though very small must contain many score, perhaps hundreds, of molecules, all pulling upon the molecule at the center and in turn being attracted to it. As long as the molecule is well within the confines of the liquid this pull is equal in all directions, which is the reason it is so difficult to measure in ordinary ways.

### At the Surface

But suppose the molecule, in its erratic motions through the body of the liquids, approaches the surface, so that a part of this sphere of influence projects above the surface, into a region where there are no or few molecules. It is evident that the pull downward is now

greater than the upward pull, so that the molecule is pulled back into the body of the liquid, unless it is moving so fast that its kinetic energy suffices to pull it away from this backward attraction. This last is what happens in evaporation, and since only the more rapidly moving

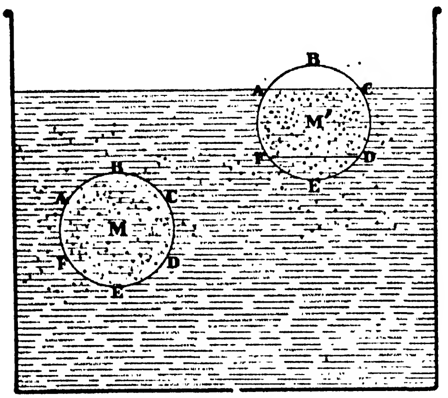


FIG. 3. THE MOLECULE M IS PULLED EQUALLY IN ALL DIRECTIONS BY THE MOLECULES WITHIN THE SPHERE OF INFLUENCE ABCDEF. THE FORCE ON MOLECULE M′ IS GREATER DOWNWARDS BY THE ATTRACTION OF THE MOLECULES IN THE SPACE DEF.

molecules are able to get away in this manner, those which are left behind, with less kinetic energy, are cooler, and the liquid gets cooler and cooler unless more heat is continually supplied from the outside. This heat necessary to keep up the evaporation is called the heat of evaporation, and evidently must vary with the attraction between the molecules.

It is evident then that the molecules near the surface of a liquid are in a different condition from those in the main body, in that the former are being pulled back into the liquid by the attraction of the molecules below. This results in an increase of density in that part of the liquid near the surface, and within this thin layer (not thicker than the diameter of the imaginary sphere of influence) such curious phenomena arise as were mentioned in the beginning of this chapter.

### SURFACE TENSION

Evidently it is of little difference whether we think of this force as being applied from within or without, and we are accustomed to say that the surface of a liquid acts as if it were covered with an elastic film under a tension, *i.e.*, continually trying to contract, so a drop of liquid, like a balloon, must assume a spherical shape, with the surface film taking the place of the rubber.

There is this difference to be noted, however, between the action of the rubber and of the surface film. When we stretch the rubber, we are pulling the molecules farther apart, and the force increases with the stretch (Hooke's law); but when the surface film is stretched, as when we blow a soap bubble, we are simply bringing more molecules to the surface, and the tension does not increase. The constant force that must be exerted at right angles to a line one centimeter long in the surface of a liquid to keep it from contracting is called the surface tension. It varies with the internal stress which is its cause, but is only an infinitesimal fraction of it.

### MEASUREMENT OF SURFACE TENSION

When we dip a rectangular wire frame into a liquid and then withdraw it care-

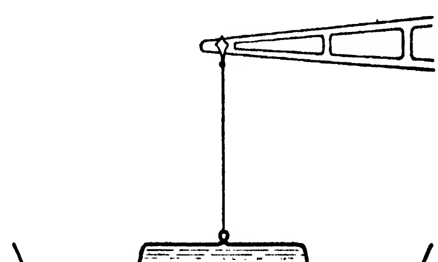


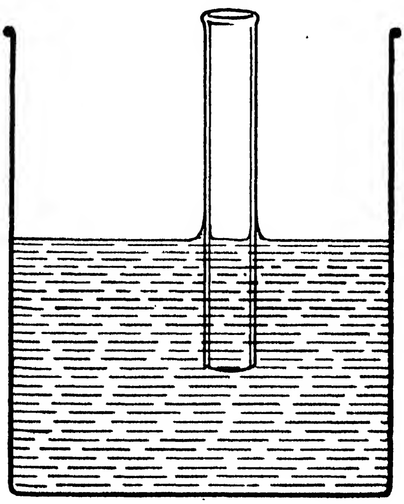
FIG. 4. MEASURING SURFACE TENSION BY BALANCE.

fully, a film of the liquid adheres to the frame, which may be drawn upward a

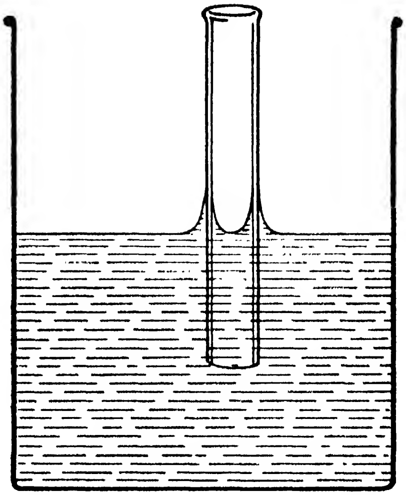
quarter of an inch or more before the film breaks. If the frame be attached to a delicate balance, we can measure the force necessary to hold the wire frame in position and the extra force required when it is carrying the film, which is trying to pull it back below the surface. It is a delicate operation, but when we use pure water and divide the average of several trials by twice the width of the frame (since there is a film on each side of the frame) we get something less than 75 dynes per centimeter as the force required to rupture this film.

### Capillarity

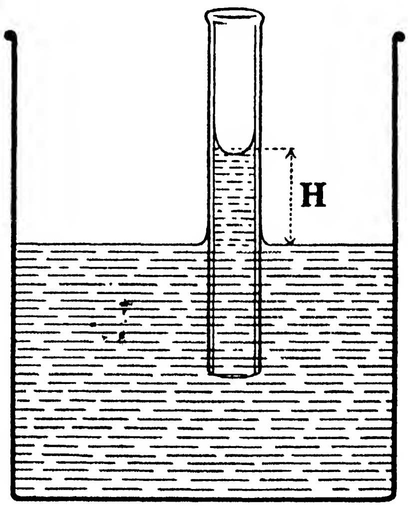
Let us look into the reason for the rise of water into the meshes of the cotton cloth. Water, as well as a good many other liquids, has the power of rising in small tubes (capillary, from Latin, *capillus*, "hair") far above the level of the liquid outside the tubes. Some liquids are depressed below the surface. It depends upon whether or not the liquid wets the sides of the tube —whether the power of adhesion is greater or less than the power of cohesion. Mercury in glass tubes gives the best example of the latter case. The cohesion of molecules of mercury for each



A



B




C

Fig. 5. Illustrating the rise of water in a capillary tube.

other is much greater than the adhesion of molecules of mercury for glass. But mercury *will* rise in a copper tube, since the adhesion of mercury for copper, with which it forms an amalgam, is very great.

Now suppose that a glass capillary is dipped into water. If the glass be free from grease or any dirt, a film of water immediately reaches up the inside of

the tube from the surface of the water. Owing to the tendency of the film to assume the smallest possible shape, it no longer remains as in Fig. 5 (A), but assumes a concave shape as at (B). This film continues to contract, pulling a column of water up after it, as in (C). This allows the film to reach up higher, and the column of water in turn is pulled higher. It is evident that this will go on until the downward pull of the water (its weight) is equal to the maximum upward pull which the film is able to exert. The weight of the water can be calculated: It is the volume $\pi r^2 h$, where $r$ is the inside radius of the capillary, $h$ the height of the liquid, multiplied by $d$, its density. The upward pull of the film is the pull, T, per centimeter of the length, which in this case is the inside circumference of the capillary; *i.e.*, the pull of the film is $T\ 2\ \pi r$. Equating these two expressions and solving for T, we have $T = \frac{1}{2} r\ h\ d$.

It is evident that the height to which the liquid rises in a tube which it wets is inversely proportional to the diameter, which fact can be easily verified by trying tubes of different sizes. This justifies the plea for frequent cultivation of the garden soil in a dry time, for by breaking up the cracks, we prevent the access of the drying air to the roots of the plants, and by making the interstices between the clods smaller, we increase the depth from which the water may rise by capillary attraction.

This tendency of a surface film to contract to the smallest possible dimensions is also shown by the behavior of a soap bubble. If the bubble is blown on the bowl of a pipe, a small but constant pressure must be maintained to prevent its shrinkage. Films may be formed on wire frames of various shapes, and they invariably take that shape that mathematically gives the minimum surface. Very interesting cases are discussed in that fascinating little volume, "Soap Bubbles and the Forces Which Mold Them," by Boys.

### Effect of Impurities

Some substances increase, some decrease the surface tension. Alcohol is one of the former. Scatter a little fine cork dust over the surface of water, then bring down near the surface a rod wet with alcohol. Even before it touches the water, the particles will fly away as if repelled. The fact is that a little of the alcohol vapor is absorbed, and this so weakens the surface film at that point that the surrounding surface draws away, carrying the dust with it. An even more striking experiment may be performed with a little boat a couple of inches long, of paraffined paper. There must be a little compartment in the stern, with a number of openings to the rear. In this compartment put a wad of cotton wool wet with alcohol. Place the boat in a tub of water, and as the alcohol oozes out and diminishes the pull backward, it will move forward at a surprising rate—*pulled* from the front and not *pushed*, as boats usually are.

We are told (Prov. iii, 31) to beware of looking "upon the wine when it is red . . . when it moveth itself aright." Just what is meant by this expression? Well, the wine will creep up the side of the glass in a thin sheet, drawn by capillary attraction, but in this condition, evaporation of the alcohol will take place very rapidly. The more watery liquid left will have a sufficiently high surface tension so that it will be drawn together into drops which will run down the side of the glass, forming the "tears of wine." But this "moving itself aright" occurs only with wine that is 15 per cent. to 20 per cent. strength—strong enough to be intoxicating.

For my tonsilitis last winter, the doctor asked me to try a new remedy, "S.T." I asked him what the letters stood for, and he laughed and said "Surface Tension" and explained that its

significant ingredient was a chemical that so reduced the surface tension of the liquid that it reached down into the crypts that harbored the germs that caused the trouble. The medicines used ordinarily simply reached over the surface, as the film of water stretches over meshes of the sieve, as described above.

Camphor also diminishes the surface tension, and if a little crumb of gum camphor be dropped on the surface of *clean* water, it will spin about like a crazy water-bug. The little projections on the surface of the crumb dissolve most rapidly, and the tension is weakened most in that vicinity, so the camphor is drawn away in the opposite direction. In a moment, solution is occurring most rapidly at some other point, and the "bug" darts off in another direction.

But now, while the dance is most vigorous, touch the surface with the tip of your finger, which has been drawn over your hair. The motions stop instanter. The explanation is that a film of oil from the finger has spread over the surface of the water, so that the surface tension everywhere has been reduced to such a degree that the solution of the camphor no longer makes any difference.

Lord Rayleigh allowed a weighed drop of oil to spread over a surface of known area, and calculated that the thickness of the oil film when the motion of the camphor was stopped was two one-millionth of a millimeter. Half of this thickness produced very little effect; more than two millionths diminishes the surface tension slightly, not at all proportionally. Other experiments seem to show that at the critical thickness, there are just enough molecules to cover the surface one layer deep, and that the long oil molecule, consisting of a chain of carbon atoms, is standing on the end which forms a chemical union with the water molecule. A smaller amount of oil means that there are not enough molecules to cover the surface, so that we have practically a water surface; more oil means simply another layer of molecules on top of the first, but no essential difference in the character of the surface.

Soap (and alkaline substances generally) is another substance that diminishes the surface tension of water. The reason that it is so difficult to cleanse the skin with pure water is that the water forms a film *over* the particles of dirt. The presence of the soap so reduces the surface tension that water may be worked around and *under* the dirt, thus dislodging it. (There is also a chemical action,—emulsification of the grease by the free alkali of the soap,—and the adsorption of the dirt by the colloidal particles of the soap that help out. Washing your face is not a simple thing.)

If soap diminishes the surface tension of water, it may be asked why we can blow *soap* bubbles successfully, but fail with pure water. This involves energy considerations and will be discussed later.

### Effect of Temperature

Surface tension decreases as the temperature increases. Here are two splinters of wood floating on the surface of water, a few millimeters apart. I touch the water between them with a red-hot wire, and immediately they fly apart. The surface tension between them has been weakened, and the unchanged pull in the other direction has pulled them apart. Perhaps you will remember a kettle full of not too greasy soup, wherein, while hot, the grease formed a thin layer on the whole surface, but as the soup cooled, collected in rather thick drops. The increased surface tension of the cooling grease pulled it together. This property explains the method of removing grease from a fabric. Put a piece of blotting-paper under the cloth and hold a hot iron over the spot. The difference in the surface tension of the

hot grease above and the cooler grease below causes it to become concentrated below, and it is drawn away into the blotter.

Let us look into the philosophy of this a bit. Surface tension depends, as we have seen, upon the attractive force between the molecules. But there is another force in action between these bodies. They are in rapid motion, and because of their elasticity, every collision causes a rebound—they are, because of this motion, being driven apart. This motion is no more or less than heat, and the temperature varies as the average of the square of the velocities, or the "mean square velocity" (which is different from the square of the mean velocity). Here we see an explanation of the well-known fact that bodies expand when heated. Evidently two opposing forces are at work here, and the decrease of surface tension with the rise of temperature follows necessarily.

Evaporation is merely the escape of the more rapidly moving molecules through the surface, as before said.

The addition of these flying molecules from the liquid to the space above the liquid produces a pressure of its own called the vapor pressure of the liquid. Of course it rises with the temperature, and when the pressure has become equal to that of the atmosphere (14.7 lbs. per square inch) we have reached the boiling-point of that particular liquid. Provided we supply heat fast enough, vapor is emitted from the liquid in sufficient quantities to push the atmosphere away, and the space above the surface is occupied solely by the vapor of the liquid. But no matter how fast we supply heat, the temperature does not rise any more, for as fast as the molecules reach this temperature, they escape through the surface.

It is evident from this discussion that we should expect a close connection between the boiling-point and surface tension. The following table illustrates this:

| | Boiling-point | Surface tension |
|---|---|---|
| Ether | 34.6° C | 19.3 dynes |
| Alcohol | 78.0° C | 25.3 " |
| Benzol | 80.2° C | 30.6 " |
| Water | 100.0° C | 75.8 " |
| Mercury | 357.0° C | 441.3 " |

### Heat of Vaporization

I have said that it is impossible to raise the temperature above the boiling-point. This is not strictly correct. It is possible, provided you prevent the escape of the more rapidly moving particles. But this raises the pressure, as the steam engineer very well understands. At 180° C., if the steam is confined, the pressure is nearly ten times what it is at 100° or the ordinary boiling-point.

It is evident that the heat energy needed to vaporize one gram of water, what we call the latent heat of vaporization, amounting to 540 calories, is work that is required to do two things: (1) Push back the atmosphere from the space to be occupied by the steam and (2) tear the molecules away from each other or overcome this force of cohesion we have been speaking of. Let us call the science of arithmetic to our aid:

When the cubic centimeter (one gram) of water at 100° C. becomes steam, at 100° C., its volume becomes 1,672 cc., an increase of 1,671 cc. In doing so, it has to overcome a pressure of 14.7 pounds per square inch, or 1,033.6 grams per square centimeter, or 1,012,928 dynes per square centimeter. The work done is found by multiplying this pressure by the change of volume, 1,671 cc., and we get over 169 joules or about 40 calories. This leaves very close to 500 calories as the work that has to be done in pulling every molecule in a gram of water through the surface—away from the

counter attraction of its fellows. This would lift 120 pounds to a height of 6 feet.

### Critical Temperature

This relation between temperature, external pressure and surface tension may be illustrated by a very pretty experiment. Within this little sealed glass tube, we have one gram of ether (Fig. 6). Above it, nothing but ether vapor. The air was driven out before it was sealed. The surface of the liquid forms that saucer-shaped meniscus which is characteristic of the liquid condition. Picture to yourself the molecular activ-

Fig. 6.

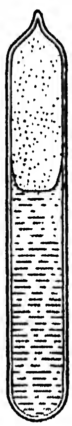


Fig. 7.

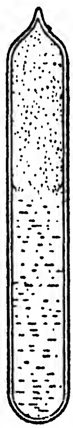


Fig. 8.

ity going on within this little tube; millions of molecules bumping about, colliding with each other, and darting off in a new direction. Some approach the surface, only to have their motion checked by the pull of the molecules behind them; others are going so fast that they break through, perhaps to be hit by other molecules already there and knocked back, perhaps to get away entirely; and, except for the fact that their mean free path now is perhaps a hundred times their own diameter, instead of three or four, there is no difference in our pictures of the ceaseless activity that is going on above and below the meniscus. Now I begin to heat the tube. As before explained, we are increasing the velocity of the molecules. You will notice (Fig. 7) that the volume of the liquid, in spite of the increased pressure of the vapor above it, is increasing; the molecules, therefore, must be getting farther apart. This means that the attraction between them is less, and the evidence of this is that the meniscus is flattening out. Note that while the density of the liquid is decreasing, that of the vapor above is increasing for two reasons: the volume is less and there are more molecules there. After a while we notice that the meniscus is nearly flat, and is becoming indistinct (Fig. 8). Soon it vanishes entirely, and we have in the tube—what? Gas or liquid? It is of the same density throughout, and consequently the surface tension has disappeared. We no longer have a liquid with its vapor; it is a gas. The temperature at which this change takes place is called the critical temperature for that substance. Above this temperature, no amount of pressure can convert the gas to a liquid.

### Capillarity and Hydrostatic Pressure

The rise or depression of liquids in capillary tubes may be explained in another way, although it comes to the same thing in the end. Let M (Fig. 9) be a

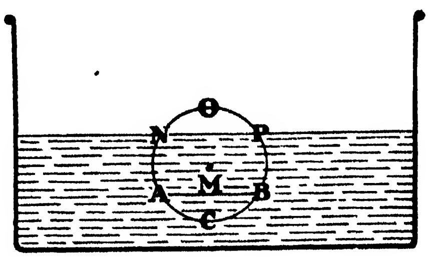



Fig. 9.

molecule below the surface of a liquid. Ordinarily, it is pulled in all directions by the surrounding molecules within the sphere of influence. But if part of that sphere, say the portion *nop*, projects above the surface, the pull of an equal

portion, *abc*, is now unbalanced and exerts a force, *p*, pulling the molecule back downward. This force is transmitted through the liquid, of course, so that the total force, P, below the surface, is not only that due to the weight of the liquid (which depends upon the height times the density, or *hd*), and the barometric pressure, *B*, but in addition this molecular pressure, *p*. Or in symbols, $P = B + hd + p$.

Now, suppose the surface is concave, *i.e.*, the liquid wets the tube, as in Fig. 10, M being the same distance below the surface as before. M is now pulled back by the molecules within the space *def*, a volume evidently smaller than *abc*, consequently *p is less beneath a concave surface than beneath a flat one.* This would make P less within the tube than in the free liquid outside at the same level, but since liquids transmit pressure so easily, this is impossible, and the water is forced up the tube until the extra hydrostatic pressure, *hd*, makes the pressure inside the tube equal to that on the outside.

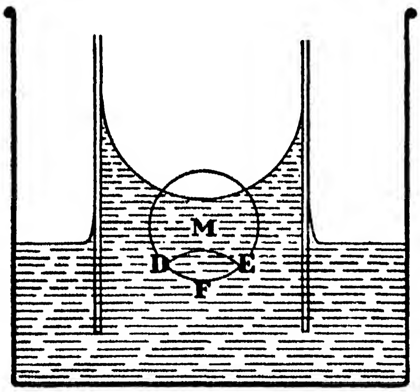



FIG. 10.

A similar line of reasoning shows that below a convex surface (liquid does not wet the tube, see Fig. 11) the *pressure is greater,* consequently *hydrostatic pressure must be less* to balance conditions, and the *liquid therefore is depressed* in a tube which it does not wet.

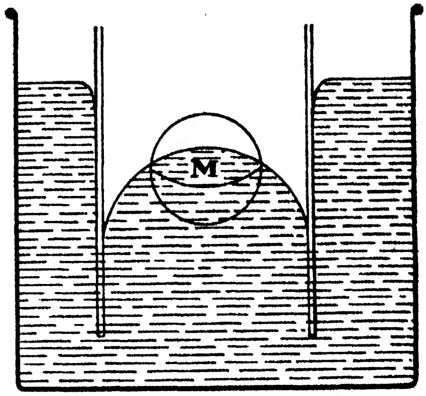



FIG. 11.

### DROPS AND BUBBLES

The curvature of the surface is measured mathematically by the reciprocal of the radius of curvature, that of a flat surface being zero, since a flat surface may be looked upon as having an infinite radius, and one divided by infinity is zero. If the curvature of a convex surface is considered positive, that of a concave surface is negative, and it will be easy to remember that beneath a surface of positive curvature the pressure, *p*, is more than, and beneath a surface of negative curvature less than that beneath a plane surface. (Incidentally, mathematicians will remember that a quantity changes its sign in passing through zero or infinity.) Plainly, this difference of pressure increases with the curvature, as may be experimentally proved by the behavior of a drop of liquid in a tube of small but varying diameter. If

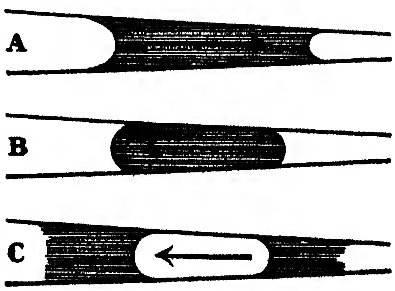



FIG. 12. DROPS AND BUBBLES.

the liquid wets the tube, the drop will assume the shape shown in Fig. 12A, and move toward the right, *i.e.*, towards the end which has the greater negative curvature, where $p$ is less. If it does not wet the tube, the drop assumes the shape shown in Fig. 12B, and moves toward the left. If, however, we have a bubble of air in a tube filled otherwise with liquid which wets the tube, the bubble moves to the left (12C), and the greater the difference between the curvatures at the ends of the bubble, the greater this tendency to move. (Compare this condition with two capillary tubes of different diameters. The tendency of the liquid to rise in the tube is greater the smaller the tube.) If you try to blow out the air and water from a tube ending in a capillary, you will find it almost impossible, owing to this opposing force.

This has an application that is of the greatest importance to caisson workers. At the great pressure to which they are subjected, an unusual amount of air is dissolved in the blood, the amount being proportional to the pressure. When they come out from this pressure, the blood can no longer hold the gas in solution, and it appears in tiny bubbles in the blood stream. Bottled pop acts similarly when the stopper is removed from the bottle. These bubbles obstruct the flow of blood through the capillaries, and we have the condition illustrated in Fig. 12C. This causes cramps in the muscles known as the "bends." One would think that any tube that would pass blood would also pass air, and so it would be if the tube were filled with air alone. But as a bubble approaches the narrowing, almost microscopic part of the capillary, the pressure behind the smaller end becomes greater than the driving force of the heart.

### Surface Tension and Electric Charge

A useful application of this principle has been found in a device for making and breaking an electric current. A small glass tube ending in a capillary is filled with mercury and connected with one pole of a source of electricity, as in Fig. 13. The other pole is connected to

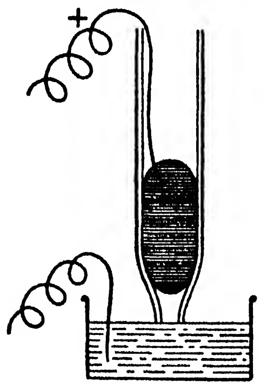



Fig. 13. Capillarity electrical interrupter.

a vessel of sulfuric acid, placed beneath the vertical tube. As soon as the convex surface of the mercury becomes charged, the self-repellent action of the charge on the surface partially neutralizes the surface tension of the mercury. The mercury drops down the tube, therefore. But the instant it comes in contact with the sulfuric acid, the latter is electrolyzed; gas is formed which breaks the electrical connections; and the surface tension of the mercury draws it back into the tube where it again accumulates an electric charge.

This action of an electric charge in diminishing the surface tension of a

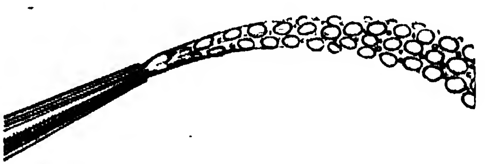


Fig. 14. A jet of water breaks up into drops because of surface tension.

drop may be shown in a very pretty manner by bringing a charged rod near a jet of water. Ordinarily a small jet

breaks up into drops, owing to the surface tension acting on the column of water. But when these drops are

FIG. 15. A CHARGE OF ELECTRICITY ON A JET OF WATER, BECAUSE OF ITS SELF-REPELLANT ACTION, NEUTRALIZES THE CONTRACTILE ACTION OF SURFACE TENSION.

charged by induction from the rod, the surface tension is so neutralized by the presence of the self-repellent charges that the drops run together again to form a solid column—rather, the column does not break up.

### SURFACE TENSION AND EVAPORATION

It is not necessary that the capillary tube be dipping into water to show the difference of level discussed on page 153. For if a capillary (Fig. 16) sealed at its lower end be supported in the same way, and the entire system then placed beneath a bell-jar, the water will distil over from the flat surface and condense on the concave surface within the tube, until the difference of level is the same as before. This seems puzzling until we remember the condition of a molecule of water vapor above the surface at less than the diameter of the sphere of influence. The molecule M within the closed tube is pulled equally in all directions except downwards by the other molecules of vapor inside the sphere of influence, represented by the circle. The downward force is greater because of the greater number of molecules per volume below the surface of the liquid, and this downward attraction is evidently greater below the curved surface than below a flat surface by the attraction of the molecules within the volumes ACES. Remembering that a constant interchange is going on between the

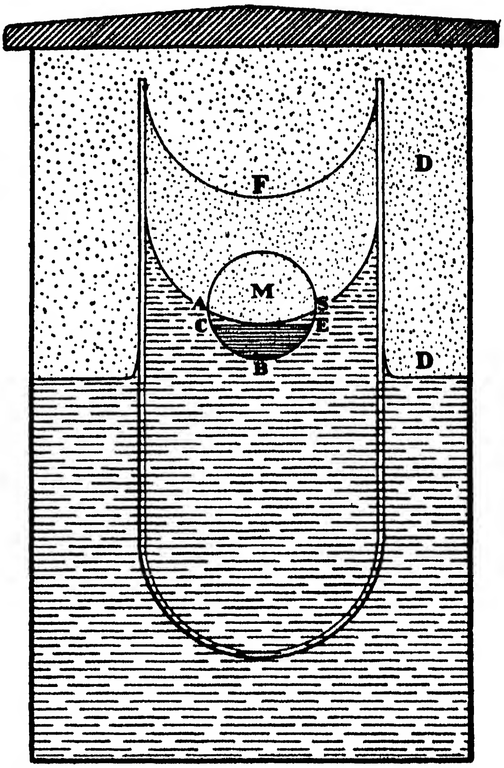



FIG. 16. LIQUID DISTILLING OVER FROM A FLAT TO A CONCAVE SURFACE.

liquid and vaporous conditions, it is plain that more molecules will enter the concave surface and that this must go on until the level within the tube has reached a height, say at F, where the diminished number of molecules per cubic centimeter (remember the rarefied air on the mountain top) just balances this greater tendency to pass below the concave surface, since the evaporation is more rapid into a region with fewer molecules. Of course the opposite condition prevails beneath a convex surface, and we might sum up by the statement that the vapor pressure, which measures the tendency for a molecule to pass through the surface or condense, is greater immediately above a concave, less above a convex surface. Compare this with the previous discussion of the pressure beneath the surface, and re-

member that difference increases with the increase of curvature.

Let us follow this a little further. Suppose the convex surfaces are on two drops of different sizes in a saturated vapor. There will be a greater tendency for the vapor to condense on the larger drop than on the smaller, consequently there will be a tendency for the larger drops to grow at the expense of the smaller The smaller the drop, the less the tendency for the vapor to condense, so that by the time we get down to molecular dimensions, there is, theoretically, no tendency at all, and in a region with no drops, the space may become supersaturated with vapor, with no tendency toward the formation of drops, although the liquid may condense slowly on the walls The situation is entirely changed, however, if there are nuclei present, such as dust particles, to furnish the curved surfaces. Then condensation occurs, and we have a cloud of drops, each with a particle of dust at the center. This is the explanation of the prevalence of fogs in the city, where there is an abundance of smoke and dust particles to serve as centers of condensation. London, with its millions of tons of soft coal burned every year, much of it in open grates with their incomplete combustion, is the best example of this. They should adopt the slogan, "Less smoke, less fog." This is not to say that no smoke (or dust) would mean no fog, for ionized particles or molecules will serve as centers of condensation, and when the saturation reaches a sufficiently high point, drops will form anyway. It is possible that the "cloudbursts" which often occur in the mountainous regions of the west, where the air may reasonably be expected to be freer of dust than air near large cities, are to be explained by the presence of a very large body of highly supersaturated air. When drops do begin to form, condensation takes place (*i.e.*, drops grow) with great rapidity.

For precisely similar reasons, bubbles within a liquid are formed with great difficulty unless there are nuclei present. Here we have a surface that is concave towards the vapor, and the tendency for molecules to pass from the liquid to the vaporous side of such a surface diminishes with the size of the bubble. In vessels quite smooth on the inside, pure liquids may be heated far above the boiling-point before ebullition begins. But when it does begin, it is apt to proceed with explosive violence, since the growth of the bubble makes it progressively easier for evaporation to occur at the surface of the bubble.

### Surface Energy

Evidently, the surface of a liquid is the seat of potential energy, just as a spring which has been extended is said to possess potential energy. The amount of this energy can be calculated easily, if we remember that the definition of surface tension is that force in the surface of a liquid exerted at right angles to a line one centimeter long. If we imagine ourselves stretching the surface by a pull at right angles to this line, we must do work. By the time we had displaced the line one centimeter, or increased the surface one square centimeter, the work would have amounted to a number of ergs equal to the value of the surface tension in dynes. When the surface contracts, work is done by the surface, and the total "available" energy is that given by contracting to the smallest area, *viz.*, a sphere, plus the amount of heat that has entered the liquid from the outside. In the case of water, at zero centigrade, this amounts to 117.3 ergs per square centimeter.[1] As stated before, the presence of impurities may increase or decrease this amount. Whenever the potential energy of a system becomes less, kinetic energy becomes available for doing ex-

[1] Edser's "Physics," p. 295.

ternal work. Thus a watery solution may *do work* either by diminishing its total surface, or by a change in the chemical constitution of its dissolved material in such a way that the resulting mixture has a smaller surface tension. There have been several more or less successful efforts to explain the mystery of muscular contraction by changes in the surface tension within the muscle fibers.[2] Certain it is that, although heat is involved in the performance of work by muscles, it is a by-product, and by no means the intermediary by which chemical energy is transformed into mechanical energy. Reasons for this belief cannot be given here.

Loeb's famous work on the fertilization of the egg of the sea-urchin showed that the changes that took place were accompanied by changes in the surface tension of the egg. When these changes in surface tension were produced by changes in the chemical constitution of the medium in which the egg was immersed, cell division (development) proceeded for a time quite as if the cell had been fertilized in the regular way.

Every high-school pupil has heard of the law of conservation of energy, sometimes spoken of as the first law of thermodynamics to remind us that heat energy comes under the same generalization. But the second law of thermodynamics is of equal importance to those trying to *use* energy. It refers to "the running down" of energy and is the death-blow to every scheme of perpetual motion. To give a few examples: A wound-up clock has a certain amount of potential energy; as it runs down, this potential energy becomes kinetic energy (it moves the hands; it strikes the chimes; it might keep a lot of mannikins in motion) and a *part of this is dissipated as heat, never to be recovered.* We shall never have a clock that is able to wind itself up quite as tight as when it started. Part of the potential energy of the water above the falls is dissipated into heat as it passes through the motors. The compressed gas or steam expands; again potential energy is converted to kinetic energy with the loss of a fraction in dissipated heat. In all the experience of mankind for thousands of years, nothing has happened to controvert this statement of the second law: *The potential energy of the universe tends to a minimum.* We have seen how this is illustrated in the case of surface tension by a shrinkage of the surface. But we can carry this a little further. If the liquid has dissolved in it something that *lowers* the surface tension, it will be lowered more, that is, the potential energy will be further diminished, by a concentration of the dissolved material in the denser layer that forms the boundary between the solution and the surrounding medium. Albumen in water is such a substance. The amoeba is said to be a blob of "protoplasm with no cell-wall," *i.e.,* no wall that will take a stain and so be differentiated under the microscope. But if there is a *surface,* there is a *surface tension,* and in this case with more of the albuminoid portion in that layer, which, because of the surface tension if nothing else, must be denser than the main body of the solution. Perhaps this is the beginning of all cell walls.

We have wondered why we can blow soap bubbles and not water bubbles, even though the water has a higher surface tension than soap solution. Just because the soap solution does have a lower surface tension, it is more concentrated near the surface. Suppose now that the bubble starts to blow out, the first step in a break. The first thing to happen would be a thinning of the layer of soap at that spot, with a strengthening of the surface as it became more watery and less soapy, and the bulge would be im-

[2] Howell's "Physiology," p. 75.

mediately pulled back. So the entire sphere, though weak, is under the sway of perfectly balanced forces, and hence stable.

A film of oil on the surface of a stormy sea has the same effect on small waves. Under ordinary conditions, wherever a wavelet sticks up, the wind catches it, beats it back with emphasis which produces a bigger wave, and so on until waves are "mountain high." But if the first little wave has to push through a film of oil with a smaller surface tension, it is treated like the first bulge on the surface of the soap bubble—it is immediately pushed back into shape before the wind catches it. The huge breaking waves, so dangerous to shipping, are transformed into long, smooth rollers which even small boats may ride safely.

Speaking of the dangers of the great deep reminds us that, if you ever are shipwrecked, you don't need to go without fresh water. Remember that since salt *increases* the surface tension of water, the rule we have just been discussing shows that if potential energy is to be a minimum, the salt must draw back from the surface, leaving a film of fresh water spread over every body of salt water, so all you need is patience and a sufficiently delicate skimmer to get all the fresh water you want.

And here we may as well stop, not because the subject is exhausted, but probably the reader's patience is.

# SCIENCE SERVICE RADIO TALKS

## PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

# HEAVY-WEIGHT HYDROGEN

By Professor HAROLD C. UREY
DEPARTMENT OF CHEMISTRY, COLUMBIA UNIVERSITY

I HAVE been asked to talk to you this afternoon on the subject of "Heavy-weight Hydrogen," which Dr. Brickwedde, Dr. Murphy and I discovered about a year and a half ago, and which at the present time is proving to be a very interesting substance in the sciences of chemistry and physics. In fact, some five or six university laboratories in the United States are very actively engaged in investigating the properties of this substance, and its commercial manufacture has been undertaken by at least one company and is well under way. In order to tell you something of the interest which physicists and chemists have in this hydrogen, it is necessary to tell you how it fits into a broad development of these sciences which began over a hundred years ago, and which is more interesting to-day than it has been at any time in the past.

But before doing so, I must tell you a little about the differences between this new form of hydrogen and the previously known variety, and give you the names of the two varieties.

The previously known variety of hydrogen has been referred to among scientists as "hydrogen one," while the heavy-weight hydrogen has been known as "hydrogen two." The "one" and "two" refer to the weights, or more correctly, the masses of the single atoms of the two varieties, the one having a mass of 1/16 the mass of the oxygen atom, and the other 2/16 of the mass of this atom. Thus, if the oxygen atom is assumed to have a mass of 16, these two varieties of hydrogen have masses of 1 and 2, respectively, and hence the names. Recently we have proposed the names protium and deuterium from the Greek words meaning first and second, for these varieties, but in this talk, I shall use mostly the names hydrogen one and hydrogen two. With this brief statement, let me return to the historical story of atoms as it bears on the story of hydrogen two.

Among the great variety of material substances which we observe about us, there are about ninety which we call elements. These are substances which we can not break up by chemical means into simpler substances. In 1803 John Dalton suggested that all matter consisted of very small particles which he called atoms. All the atoms of an element were assumed to be precisely alike as to size, weight and chemical behavior. Chemists early discovered methods for determining the relative weights of these atoms and Prout, in 1815, pointed out that the weights of these atoms appeared to be multiples of that of the hydrogen atom. He made the hypothesis that the atoms of the elements were made up of closely packed hydrogen atoms. Elements were found which contradicted this hypothesis, and it had to be abandoned toward the end of the nineteenth century. It has been revived recently, and this hypothesis that the elements are all composed of the element hydrogen one is of interest to-day in connection with the rare hydrogen two.

We now turn to another interesting

chapter of this subject. During the closing years of the nineteenth century, the phenomena of radioactivity were discovered, and it was found that there are a very considerable number of elements which are spontaneously changing, one into another. As a result of the study of these transformations of certain elements into others, it was found that some of these radioactive elements have exactly similar chemical properties, but that the weights of the atoms are not identical and the radioactive characteristics are different. Thus radium and mesothorium 1 can not be separated chemically, but radium requires about 1,800 years for one half of it to change into another element, while mesothorium 1 requires only seven years to make a similar amount of change. Also their atomic weights are 226 and 228, respectively. Such atoms, having similar chemical characteristics but different atomic weights, are called isotopes. Many examples of this kind were found among these radioactive elements. The next step in the development of our subject was made when it was shown that ordinary elements, such as neon, familiar to us all in the neon signs, chlorine, one of the constituents of table salt, and many others, consisted of mixtures of atoms having very similar chemical properties, but differing in their weights. In recent years, Aston in England has investigated the composition of a great many of our elements, and found them in the majority of cases to be mixtures of such isotopes. Recently, investigators in this country have found that such ordinary elements as oxygen, nitrogen and carbon also consist of such mixtures. These individual isotopes were found to have atomic weights which are very nearly whole numbers, so that we feel certain that Prout's hypothesis is at least partially true when applied to the individual isotopes and that the atoms of the elements are probably composed of a whole number of hydrogen one atoms.

This situation was well recognized two years ago, and hence we hoped to find an atom of atomic weight two, for it would consist of only two hydrogen one atoms and be the simplest of these complex atoms.

Professor Birge, of the University of California, and Dr. Menzel, of the Harvard Observatory, gave reasons for believing that hydrogen two might be present to the extent of one part in 4,500 of the hydrogen one variety. An isotope as rare as this had never been detected, and thus it was necessary to concentrate the isotope. This was done by Dr. Brickwedde at the Bureau of Standards at Washington by distilling liquid hydrogen at −466 degrees Fahrenheit. In this way, the concentration of hydrogen two was increased to one part in 1,100, which enabled Mr. Murphy and myself to prove its existence by means of its spectrum. Since then Dr. Washburn, of the Bureau of Standards, has found that the hydrogen two can be concentrated by the electrolysis of solutions of caustic potash. This method has been used by a number of investigators to prepare samples of hydrogen containing high concentrations of the hydrogen two. In fact, Professor Lewis, of the University of California, has secured a small sample containing 99.5 per cent. of this new hydrogen, or deuterium, as we have agreed to call it. In the next few years deuterium, this new form of hydrogen, is destined to be the subject of much serious work, both in chemistry and physics, and I think it may interest you if I say something of these possible developments.

In recent years we have come to understand the structure of atoms much more thoroughly, and we find that an atom consists essentially of two parts. First, there is the central sun of a miniature solar system, which carries a positive charge of electricity. Moving about this in some way which we can not quite visualize, but which must be some-

what like the planets of the solar system, are a considerable number of negatively charged electrons. Once we have fixed the number of electrons of any atom, the chemical characteristics are determined. Thus, if there is one electron to each atom, the element is hydrogen; if two, the element is helium; if three, lithium; if four, beryllium; if five, boron; if six, carbon; if seven, nitrogen; if eight, oxygen; if ninety-two, uranium, with all the other elements lying between. However, the mass of the atom is carried by the central sun of nucleus of the atom, and thus this weight is determined by the number of particles that there are in the nucleus of the atom. The nucleus of the hydrogen atom of atomic weight 1, or protium, consists of but a single particle which we call the proton. The hydrogen atom of atomic weight 2, or deuterium, has a nucleus which consists of one proton and one neutron, the latter being a particle having a weight about equal to the weight of the proton but carrying no charge. Thus the nucleus of a hydrogen atom having an atomic weight 2 would be the next to the simplest nucleus to be found in all our atoms. If we are to understand the structure of the central suns of our atoms, it is obvious that we must try to find the simplest and then the next simplest, and the third simplest, etc., of these bodies, for by understanding them we are able to go on to the more complicated types. An important beginning in this direction has been made already in the study of reactions involving these central suns of protium and deuterium and other atoms. Thus lithium of atomic weight seven and protium react to form helium, and also deuterium and lithium of atomic weight six change into helium. These reactions give out enormous quantities of energy, about one million times the energy of ordinary chemical reactions. Moreover, this deuterium nucleus is probably the only one which can be described by an exact theory, and this theory will certainly be forthcoming in the next few years. These are the principal interests of this atom to physics.

On the chemical side, a few indications of rather marked differences in the behavior of protium and deuterium are known. We are very much interested in knowing why the chemical elements behave the way they do. How does hydrogen gas burn? How do chemical reactions take place in our bodies? And many others. We know that the answers to these questions involve many factors, but one that runs through all our considerations is the effect of the weight or mass of the atoms. In the case of all the elements except hydrogen, the mass of the atoms makes such small differences in chemical behavior that they can not be measured, while in the case of protium and deuterium, the differences are easily detected. For example, waters made from these two isotopes differ in melting point and boiling point. Also, reactions involving the two isotopes must proceed with markedly different velocities. I shall be surprised if the biological effects are not interesting. Perhaps mice containing deuterium instead of protium in their bodies may move very slowly or perhaps not be able to live at all, so that the new hydrogen may be a poison. Like all new scientific toys, we do not know what tricks it will do until we have played with it a while, and—who knows?—it may turn out to be useful to all of us as well as entertaining to scientists.

# GARDENS OF TREES

By Dr. RODNEY H. TRUE

DIRECTOR, MORRIS ARBORETUM OF THE UNIVERSITY OF PENNSYLVANIA

From what we can learn from history, the first garden consisted of a garden of trees. It seems likely that these trees were cultivated date palms. The question with us immediately arises as to what characteristic quality makes a garden. To most of us the word usually suggests small plants, perhaps predominantly herbs, that are cultivated in designs of more or less elaborate nature. Perhaps gardens were once mainly trees, bearers of fruit. However that may be, date palms, olives and pomegranates have always had a prominent part in garden plantings in the older lands with milder climates.

In these later days, gardens of trees and shrubs have become arboreta, and the old gardens of cultivated fruit trees have become orchards to English-speaking peoples. In European lands, botanic gardens have been long known as usual city institutions, and few of the larger cities of Europe lack a botanic garden. These gardens are usually composite plantings in which a variety of trees, shrubs and herbs are to be found selected and arranged for the purpose of instruction and often for esthetic enjoyment.

In the New World, still fresh from the struggle between the natural forests and the demands of agriculture, the planting of trees at first consisted largely of fruit orchards. Now, however, the forest has disappeared, the production of food has claimed an area beyond the requirements of the situation and the tree for itself is becoming an object of increasing interest. Gardens of trees are being established as a part of the equipment of a land rapidly becoming one of cities. Gardens and arboreta connected with municipalities or with institutions of learning are apparently an indication of the growing age of our country and of a recognition of the fact that in the passing of forests we are in danger of losing not only our source of lumber, but also something else fully as real as timber, even though less tangible. Why, then, are public-spirited citizens, educational institutions and, in cases, municipalities, planting and fostering gardens of trees?

We may all agree, I believe, that trees, especially big trees, make a very deep appeal to the souls of men. Their great dimensions, their beauty of form and color, their long life that in duration makes us creatures of but a few seasons —all inspire in us a certain reverence. It is not hard for the tree lover to understand the tree worship of earlier times. We have our California giants remaining to testify of geological epochs, and most of us are gratified when we learn that groups of these citizens of the bygone centuries are being protected to continue to speak their message to generations yet unborn. Most of us in some degree worship trees, big trees, and hope that for centuries to come they may abide to tie together the feverish periods of human history. If we chance to live in cities with all their human noises, rushings-about, smells and sordidness, who can measure the value of trees, big trees, as a restorative to sanity and health of soul? And as the seasons come and go, with buds, flowers and seeds, gray bark and naked branches, we see the trees as nature's timekeepers, running in accord with the schedule of the heavens.

Trees also serve humbler purposes, connected with the affairs of daily living. When the wood is burned in the stove or fireplace, the glow of the coals and the glory of the flames warm us, cook our food and cheer our souls. As the body of the tree is built up through

the years out of carbon dioxide and water and a little mineral material from the soil, sunlight is stored. The quiet wood holds chained the mighty energies flashed across interstellar spaces to our earth—to our tree—and gives them up at our need.

That same tree body may be sawed and planed and polished and made into furniture, or it may be left unfinished to furnish frames for our houses. In the hands of artists it may become inspired carvings. Now the chemist dissolves it into a liquid from which a myriad of things are made, and wood threatens to rival coal tar as a raw material in the variety of things made from it.

Now, what has this to do with our garden of trees? Indirectly very much, perhaps. America has awakened almost with a start to the fact that the passing of our forests has left us heirs to a host of problems. Metals and concrete more and more are being used as substitutes for wood in construction work. Most of us have long since unwillingly ceased to use wood as a fuel. But we still feel compelled to restore the forests, and a campaign of reforestation of increasing vigor is developing. Trees are needed to protect the soil against the never-ending work of water. Erosion has already ruined vast areas of land and, by filling the streams and by choking up the channels of rivers with transported silt, forms the basis for disastrous floods.

What trees shall be planted? Much thought must go before a wise answer. Trees must be planted that will thrive in the soil and climate of our proposed forest. The sorts planted must be free from our own native diseases and from imported ones, or they must be able successfully to resist them now and for the decades to come. The trees to be planted should not only grow well, keep healthy and fit the climatic and soil conditions of regions in which they are supposed to live, but they must be able to hold the soil in place and in the end to yield an acceptable trunk when the killing time comes.

We can not rely too confidently on our native sorts. What about the chestnut? What about the white pine now suffering from the blister rust? What about other known or obscure diseases and insects that are eating our forest trees? What have other parts of the world to offer? May some Old World trees prove valuable? Here a garden of trees becomes of practical value. A collection of many sorts from many sources is likely to offer a wealth of information. Here the habit of growth, soil requirements, susceptibility to disease, methods of reproduction and a host of other characteristics may be studied. The careful, scientific records of an arboretum yield many kinds of valuable information. Materials for anatomical study, the story of the life history, none too accurately known for most of our trees, taxonomic relationships and the basis of a host of other scientific investigations will be found in an arboretum, and the greater the variety of trees and shrubs present, the wider will be the range of possibilities.

Not the least important use of such a collection will be that offered to the horticulturist and to the landscape architect. In such a collection will be found the living materials which the artist will have at his disposal in working out his designs. Here the opportunity to see and study at different seasons the appearance and behavior of plants will be most important. Here the raw materials are displayed that, used in combinations in parks and private grounds, will yield scenes of great beauty when used by the true artist.

The establishment of a new garden of trees is a sufficient cause for real and general satisfaction, and I wish in a few closing words to speak of the Morris Arboretum of the University of Pennsylvania. Mr. John T. Morris and later his sister, Miss Lydia T. Morris, members of an old Philadelphia family, for

several decades planted trees and shrubs on the acres of their country home in Chestnut Hill on the edge of Philadelphia. They traveled extensively and found special interest in the woody plants of Eastern Asia. They participated in the results of exploring expeditions to Eastern China and to other regions of that continent, and in time built up one of the richest collections of trees and shrubs in America. On her death, Miss Morris, who survived her brother, provided for the establishment of an institution to be known as the Morris Foundation, that was charged jointly with the University of Pennsylvania with the responsibility for maintaining the collected trees and shrubs under the name of the Morris Arboretum of the University of Pennsyvlania. Funds were provided for the maintenance of the arboretum, for developing and carrying on a graduate school of botany in which research in plant science should be provided for, for the publication of these results and such other material as should be decided on, for the hiring of eminent scientists to deliver lectures, for providing fellowships for advanced students and for scholarships for boys and girls studying horticulture and related subjects, for carrying on scientific studies and explorations both in our own and in foreign lands, and for the distribution of plants to the interested public. A staff of workers has been appointed and participation in explorations in China and Thibet have been provided for.

Thus, the resources of the new garden of trees will not only provide for a further development of the beauty for which the Morris home has long been known, but will serve in a distinctive way to advance scientific knowledge.

# POISON IVY AND POISON SUMAC

By L. E. WARREN

FOOD AND DRUG ADMINISTRATION, U. S. DEPARTMENT OF AGRICULTURE

There are numerous plants which, when touched by human beings, may cause irritation to the skin. Most of these, like the iris, lady slipper, oleander, flax and squill, are so nearly inert during most of the season that severe poisoning from contact with them occurs but rarely. However, there are two, poison ivy and poison sumac, which may never be handled without danger. Of these poison ivy is much the more common and, consequently, poisoning from it is much more frequent. Undoubtedly many persons, particularly children, are poisoned because they do not know how to recognize and avoid these plants. There are probably no other plants about which so much misinformation has been disseminated, or is current in the general beliefs concerning them. The nature of their poison, its methods of transmission from plant to person, how it produces its toxic effects and the treatment of the skin inflammation which it causes have been the theme of countless myths, miraculous stories and fanciful theories for more than three hundred years. Even to-day, after numerous profound researches, there are several phases of the poison ivy problem which are far from being well understood.

## What is Ivy Poisoning?

Ivy poisoning is a peculiar inflammation of the skin caused by coming in contact with poison ivy. Sumac poisoning is analogous. The symptoms range from slight redness and itching to enormous swelling with extensive blisters, accompanied by severe burning sensa-

tions. There are all gradations between these extremes. In mild cases the skin is covered with numerous small blisters. The blisters contain a colorless serum which is not poisonous; consequently poisoning can not spread from broken blisters. Pustules may form and infections may result as secondary consequences. The disease tends to recover in from ten days to three weeks. Occasionally, a persistent dermatitis follows.

Poison ivy is known by various names in different parts of the country, such as poison ivy, poison oak, poison vine, three-leafed ivy and poison creeper. The plant is found in practically every part of the continental United States, high mountains and deserts excepted. Botanists find some variations in the forms occurring in the various sections of the country. Although these differences are sufficiently great to constitute several distinct species, the general appearance of the plants and their habits of growth are so much alike that if one form is known the others usually may be recognized. Poison ivy has been known in America from the time of the early settlements. Thus, as early as 1609, more than a quarter of a century before any botanist had described the plant, Captain John Smith described the symptoms caused by touching it. He writes:

> The poisonous weed, being in shape but little different from our English yvie; but being touched causeth reddness, itchinge, and lastly blysters, the which howsoever, after a while they passe awaye of themselves without further harme; yet because for the time they are somewhat painefull, and in aspect dangerous, it hath gotten itselfe an ill name, although questionlesse of noe very ill nature.

Poison ivy adapts itself to almost every kind of soil, although it does not flourish in areas of scanty rainfall or at elevations of more than about 5,000 feet. It grows along hedgerows and fences, frequents woods and thickets, scrambles over rocks and climbs trees to considerable heights. Its habit of growth in thick shrubbery and hedges in such a way as to escape notice makes it especially dangerous to the unwary.

Poison ivy may be best recognized by its leaves and by its fruits. Each leaf is divided into three leaflets (never five, as in the Virginia creeper). The margins of the leaflets vary from smooth to more or less notched. The small greenish flowers appear in May and June, the male and the female flowers being borne on separate plants. The fruits, which are of the size of a small pea, are pale green and poisonous when immature, but ivory-white and not poisonous after ripening. The ripe fruits are filled with fat and are eaten by crows, woodpeckers and other birds. After the plants are a year or two old they develop aerial rootlets along the stems. These assist the plant in climbing. They also serve as an aid in identification. In the fall the leaves become brilliantly colored, principally scarlet and orange—a circumstance which victimizes many an unsuspecting collector. On being wounded the stems exude a cream-colored juice which becomes black on exposure to the air. The juice is thin and watery in the spring, but becomes thicker as the season advances. The poisonous constituent is found in this juice.

Poison sumac is also known as poison ash, poison dogwood, poison elder, poison tree, poison wood and thunderwood. It grows in swamps throughout the eastern half of the United States. It attains a height of from 5 to 20 feet and a trunk diameter of 4 to 10 inches. The bark of the shrub is light gray in color. The leaves are compound and are from 7 to 14 inches in length, each bearing from 7 to 13 leaflets. In autumn they take on wonderfully beautiful colors, brilliant reds, oranges and yellows predominating. In fact, no other plant common to the eastern United States has such gorgeously colored leaves at this season. In

the latitude of the Great Lakes these begin to color about the first of September, or a little earlier, and reach their most intense hues about October first. Many cases of poisoning have occurred in persons who have collected the autumn leaves for household decorations without recognizing their venomous nature. The fruit is a globular drupe of the size of a small pea and ivory-white when ripe. It is borne on long graceful racemes and hangs on the plant all winter unless sooner eaten by birds. It consists of a paper-like shell containing a mass of hard white fat, which incloses the seed. This is a hard, fluted stone about the size of a mustard seed. Crows and some other birds are fond of the ripe fruits. They digest the fat and discard the stones. The plants are disseminated by this means.

When wounded poison sumac exudes a thick juice of the color and consistency of cream, which is very poisonous. On exposure to the air the juice is converted into an almost indestructible black varnish, which is not poisonous. The early colonists in America used the juice for marking linen. In Japan the juice from a closely related species of sumac, *R. vernicifera,* has been used as a varnish for more than 20 centuries, under the name of "Japanese laquer."

Many theories to account for ivy and sumac poisoning have been advanced. The earliest explanation offered was that the plants gave off an invisible, odorless vapor or emanation which, when breathed or permitted to touch the skin, brought about the inflammatory symptoms in some unexplained way. The North American Indians had this belief in pre-Columbian days, and it is probable that the early American settlers obtained it from them. At one time it was supposed that this gas or emanation came from the plant only at night or on cloudy days. Although there has never been a particle of scientific evidence in support of this vague and irrational explanation many intelligent people still adhere to it. About 75 years ago the theory was advanced that the poisonous constituent of poison ivy was a volatile alkaloid; later that it was a volatile acid. It was supposed at one time that poisoning could take place by passing near the plants without direct contact with them. It was thought to be particularly dangerous to pass on the leeward side in such a manner that the volatile poison would be blown upon the victim. Still later the poisoning was thought to be due to bacteria.

The earliest writers associated ivy poisoning with the fabulous stories related about the upas tree of Java. According to the accounts of the early travelers the vapors from the upas tree were so deadly that persons walking under its limbs were killed almost instantly; also birds alighting in its branches fell dead. It is now known that the tales told of the upas tree were wild exaggerations and that poison ivy and this tree have nothing whatever in common.

In 1895 Dr. Franz Pfaff, of the Harvard Medical School, proved by a series of carefully controlled experiments that the poison of poison ivy was neither a gas, an alkaloid nor a volatile acid, but that it was a liquid, non-volatile substance having some of the properties of resins. It was so very poisonous that 1/60,000 of a grain of it, when dissolved in olive oil and rubbed on the skin, caused mild poisoning. Larger doses when given to rabbits by the stomach, caused death from inflammation of the kidneys, that is, Bright's disease.

The poisonous principle is found in the cell sap, in the green leaves and in the green fruits. It is not found in the pollen, or in the plant hairs which occur on the leaves and growing stems. Also the ripe leaves do not contain much of it. The poisonous principle of poison ivy is probably identical with that of

poison sumac. In the purest form so far obtained it is a dark, brownish-red liquid, resembling thick maple syrup in viscosity and general appearance. It is insoluble in water but soluble in gasoline, alcohol and melted fats. The chemical nature of this substance is not completely understood, but it has some of the properties of resins and phenols, that is, it has some of the characteristics of common rosin and of carbolic acid. Probably it is a distinct vegetable principle, just as sugar, citric acid and quinine are proximate principles of plants. The poisonous principle of poison ivy and poison sumac has been named "toxicodendrol," that of poison oak "lobinol," and that of the Japanese sumac "urushiol."

### How Poisoning Takes Place

The poison of these plants not being volatile, the only way that one may be poisoned by them is to come into direct contact with the poison. This may result from touching the plants or from coming in contact with clothing, shoes, tools, and the like, which themselves have been contaminated with the sticky juice. The poison retains its virulence for a great length of time, so that if contaminated clothing or tools be laid aside at the close of the season poisoning may result the next season on their use being resumed. There are authenticated accounts of sportsmen, gardeners and workmen being poisoned after resuming clothing or shoes which had been contaminated many months before but which had been unworn in the interim. This probably accounts for most of the stories of poisoning which are claimed to have resulted by passing the plant without touching it. Smoke from the burning plants may carry minute particles of the poison. If this touches the skin or is breathed poisoning will result. Eating the leaves of the plants (as is sometimes done in the hope of producing immunity) will result in poisoning if appreciable quantities be ingested. Smearing the juices of the plants on the body (for the production of immunity) has resulted in several very severe cases of poisoning.

### Does Ivy Poisoning Ever Cause Death?

The question whether ivy poisoning ever causes death is unsettled. Instances are known where death has occurred during a severe attack of ivy poisoning, but these were under conditions such that the existence of previous kidney disease could not be ruled out. It is conceivable that a person with Bright's disease in an advanced stage might be severely poisoned and that the combination of the two diseases might prove disastrous, whereas neither alone would have been fatal immediately. At any rate, fatalities from ivy poisoning are rare.

### Immunity

The question is often raised whether or not certain individuals naturally may be immune to ivy poisoning. Many people claim that they have worked frequently in and around poison ivy or poison sumac and have never been poisoned. They assume this to be proof of immunity. Also there are pharmaceutical preparations made from ivy or sumac which, when taken by intramuscular injection in small doses, are designed to render individuals partially immune to the poison. McNair has investigated the subject, and he believes that immunity, or at least greatly lessened susceptibility, is possible. In the opinion of the speaker, also based upon considerable study, it seems very doubtful whether there are any persons who are naturally immune to the poison. The speaker has met several of these self-styled immunes but has found only one who was willing to submit to laboratory tests with the purified poison on the skin of the arm. This person was not immune.

### How to Avoid Poisoning by Poison Ivy, Oak or Sumac

Naturally, the first requirement to avoid poisoning is to be able to recognize the poisonous plants at sight. The next is to avoid touching the plants or allowing the clothing to come in contact with them. Avoid using clothing or tools which have previously been contaminated with the juices of the plant until after they have been thoroughly scrubbed with soap-suds. If a person has touched the poisonous plants or has reason to suspect that he has, he should wash the hands or other exposed parts of the body with coal oil, rubbing alcohol or gasoline, avoiding the ethyl type of the latter and having due regard to the fire hazard. Afterward the parts should be thoroughly washed with strong soap-suds, using a flesh brush and nail file. In the absence of gasoline or denatured alcohol the washing should be done with soap-suds alone. Avoid the use of cold creams or ointments of any kind, as these dissolve the poison and tend to cause its spread by contaminating the clothing. Unless one is able to identify these plants positively, the collection of brightly colored autumn foliage from climbing plants or those having aerial rootlets or from swamp shrubs should be avoided. Also while on outings, wild berry pickings or hunting, contacts with thickets and tangled brushwood should be avoided as much as possible.

### Treatment of Poisoning

Much has been written about the treatment for ivy poisoning and many remedies recommended as "sure cures." Almost every drug in the materia medica has been proposed at one time or another. Probably the reason for this multiplicity of suggested remedies lies in the fact that ivy poisoning is a self-limited disease, that is, it tends to get well of itself without treatment of any kind. Sufferers from the disease, because of the intolerable itching and other discomforts, will try any remedy suggested by their friends. After trying one for a day or two and procuring no relief or but little they will try another, then another and so on until Mother Nature effects a cure. The last remedy tried is the one which gets the credit for the cure.

Among the remedies which have been recommended by a considerable number of physicians are aqueous solutions of sodium sulphite, dextrose, magnesium sulphate (Epsom salt), picric acid, permanganate of potash and 5 per cent. iron chloride in 50 per cent. alcohol. McNair recommends that after the application of one of these solutions, preferably the iron chloride, the surface be dried and melted paraffin applied as a spray with an atomizer. A thin layer of absorbent cotton is then laid on, followed by another layer of melted paraffin. This dressing is to be changed daily.

During the past few years extracts made from ivy or sumac have been given in the treatment of ivy or sumac poisoning. They are administered chiefly by intramuscular injections. Their introduction is too recent to determine whether they will have a permanent place in therapy. After all, in ivy poisoning, more than in almost any other disease, an ounce of prevention is worth many pounds of cure.

# WORK OF THE NATIONAL BUREAU OF STANDARDS ON INDUSTRIAL MATERIALS

By P. H. BATES

CHIEF, DIVISION OF CLAY AND SILICATE PRODUCTS, NATIONAL BUREAU OF STANDARDS

In an era such as that in which we are now living, it is rather difficult to define an industrial material. Yesterday a material or a product may have been made for the first time in the laboratory and may have been considered a matter of laboratory interest at the moment; to-day it is noted that it might have a practical use in some industry; to-morrow it will be a necessity in many industrial applications. Hence, in the broadest sense of the term, a presentation of the Bureau of Standards' work in "industrial materials" would include essentially all its activities. As very many of these have already been covered in this series, this article will be limited largely to some materials of recognized industrial importance.

However, first there will be cited the Bureau's work on an industrial material—steam—which generally would hardly be classed as such. But in many localities it is being distributed from central plants to rather distant points of application. Further, it is a material used in the conversion of the latent energy of certain materials into a more readily distributed form. For several years the Bureau of Standards has been handling, in cooperation with several other laboratories both here and abroad, a comprehensive program for the establishment of accurate and uniform tables of the thermodynamic properties of steam. The work concerns the direct measurement of latent and specific heats of water over the entire useful range from the freezing point to the critical point, and the specific heat of superheated steam at high temperatures. This program has been completed in the range 0° to 270° C. and the remainder, covering the higher temperatures, is nearing completion, except for the heat capacity of superheated steam, which will require different experimental equipment.

The dependence of the world and of the United States in particular on gasoline as a source of power is such a new development that its importance is seldom fully realized. The qualities of this product have varied widely with variations in the available supply and in the current demand. The importance of the solution of the broad economic problem of efficient use of petroleum resources was recognized some ten years ago by the automotive and petroleum industries, and a cooperative research project was established at the Bureau of Standards to meet the need. As a result, from simple laboratory tests of a gasoline one can predict the minimum temperature at which an engine can be started and the maximum air temperatures at which it will run; the tendency to knock and the tendency to dilute the crankcase oil; how well the engine will accelerate and whether the fuel is safe from a corrosion standpoint.

An interesting case of cooperation by the Bureau with a profession, through the latter's desire for a better understanding of the materials with which it

is vitally concerned, is evidenced in the studies which are being made on dental materials. The American Dental Association has for some years borne half the expense of extensive research to determine the physical properties of products used in dentistry, such as amalgams, dental gold alloys, cements, waxes and investment compounds. As a result of these researches specifications have been prepared which embody the desirable and safe characteristics of these materials. The value of this work to the dental profession and more especially to the public, measured in terms of increased effectiveness and permanency of dental restorations, can not be expressed in dollars and cents.

The very important group of materials commonly referred to as "protective coatings," including paints, varnishes, lacquers and baked and vitreous enamels, have been extensively studied at the Bureau. The work concerns both the determinations of the nature and properties of the component materials and of the finished products, and tests which will indicate in a short time what will be the length of service. These materials are of special interest at the present time due to the marked development of synthetic resins and solvents which are offering so much competition to the formerly used oils and volatile liquids of the paint trade. Some equipment used to determine in a short time the effect of light and water upon protective films is illustrated herewith. Essentially it consists of a revolving cylinder on the inside of which such films can be placed and be subjected to the action of light from the carbon arc and of water. The fusing of siliceous enamels upon cast irons and soft steel produces a type of protective coating which is finding ever increasing uses, not only in the home but in industry. Since the procedure of manufacture of such coatings requires the melting of the enamel on the heated surface of the metal, many interesting problems arise. Among these can be mentioned the determination of the coefficient of thermal expansion of both the metal and the enamel over the range of temperatures extending from that of average room temperature to that at which enamel is produced. An equally important study is that of determining the effect of each of the ingredients of the enamel upon this coefficient.

The investigations of the vitreous enamels are somewhat similar in nature to those being carried out on glass. Originally, the Bureau became interested in studies of glass for two reasons. Its chemical laboratory needed glass resistant to the commonly used reagents and the glass industry was producing a number of purported resistant glasses. Its Optical Division was interested in a more ready source of optical glass than Europe. It was therefore decided to study the effects of the various oxides used in glass manufacture on the resultant physical properties. The work was hardly under way before the late war broke out and the military branches of the government were in dire need of the special glasses required for their optical instruments. Following the request of the Navy Department, quantity production of optical glass was started and has been continued to date. At the present time 3,000 pounds of optical glass in the form of molded slabs for various instruments are delivered annually to the Navy. While producing this, investigational work is in progress covering the relation between composition of the glass and properties such as index of refraction, dispersion, density, viscosity, thermal expansion, annealing, etc. Also, the Bureau has had the honor of producing the largest optical glass disk for an astronomical reflector ever

made in the United States, and thereby showing that the country need not depend upon foreign sources for any types of the highly specialized optical glasses.

It is patriotic for American industry to use American raw material, but it is not always economical. Whether or not it will pay can be ascertained only by making an all-American product and comparing it with that made of imported raw materials. Parachutes were made of silk, which is not produced in the United States. A careful study of the properties of silk parachutes resulted in a specification. Laboratory studies indicated ways of modifying the properties of cotton. Many experimental fabrics were woven in the Bureau's textile mill and compared with the specification. The help of the Navy was enlisted in making actual trials. This information was passed on to manufacturers, and now many of our parachutes are made of American cotton instead of imported silk, and cost about half as much.

Somewhat similar cases could be cited in the Bureau's work on clays. Not long ago pot, crucible, china and ball clays, such as used in the ceramic and paper industries, were almost entirely of foreign origin. Studies have shown that these foreign materials have no properties which can not be matched by those of domestic origin. As a consequence, in many cases the foreign clays have been replaced in part or totally by clay from domestic sources.

Naturally, work of the type just mentioned would necessitate the fabrication of raw materials into finished wares. This would require the use of plants for such fabrication. In order to carry out the needed research unhampered by commercial plant limitations of all kinds, there has been erected at the Bureau a small but complete pottery. This is not the only example of similar types of installations at the Bureau. There are experimental operating plants for producing, in a small commercial way, paper, cotton goods, rubber, glass, Portland and other hydraulic cements, lime, iron and nonferruginous metals, and a steel rolling mill. These plants are necessarily supplemented by equipment for testing the products both chemically and physically in a far more detailed manner than is usually done commercially. With the exception of the glass plant, however, none of the products of these plants are used for other than testing purposes and to correlate the results of service tests with laboratory tests.

American manufacturers are constantly endeavoring to find uses for wastes. By-products are being developed, with the ultimate aim of making the tonnage of salable output from any factory approach the tonnage of raw materials used. Agriculture is now trying to follow this lead. The grain is only one half the weight of the corn plant; the other half consists of cobs, leaves and stalks, mostly the latter. There are more than 100,000,000 tons of cornstalks produced annually in the United States, and they grow in a region where lumber is relatively scarce. The Bureau has recently cooperated in perfecting a process of making boards of cornstalks, which is now in commercial use.

The query is often made as to when everything will be known about some particular material so that work on it will cease. Work on many materials has been laid aside, but not because all has been ascertained regarding it. Indeed, too frequently the more that is learned about a commodity the more information seems to be needed. Again, the demands of the industries using products are almost daily becoming more exacting and invariably because the industries

concerned have been forced to meet new demands. The construction of Hoover Dam and other large dams, for instance, has placed a new demand on concrete, namely, the evolution of less heat than commonly results when the concrete hardens as a result of the heat of hydration of the Portland cement. Two years ago there was not a laboratory in the world equipped to permit of making the determination of the heat generated during the hardening of concrete, other than a very special study after spending much time in assembling the special apparatus needed. In fact, there were only approximate data available on what the heat of hydration of cement would be and its relation to its composition, fineness, degree of burning, etc. Necessity resulting from the conditions of using cement in such huge structures has very recently caused a great amount of study in a field in which it had been assumed there was no interest, and consequently the specifications for cement for Hoover Dam will undoubtedly contain requirements limiting the heat of hydration. It appears now as though for many uses precise and accurate calorimetric work will become a matter of routine cement testing, although now

TESTING FUELS

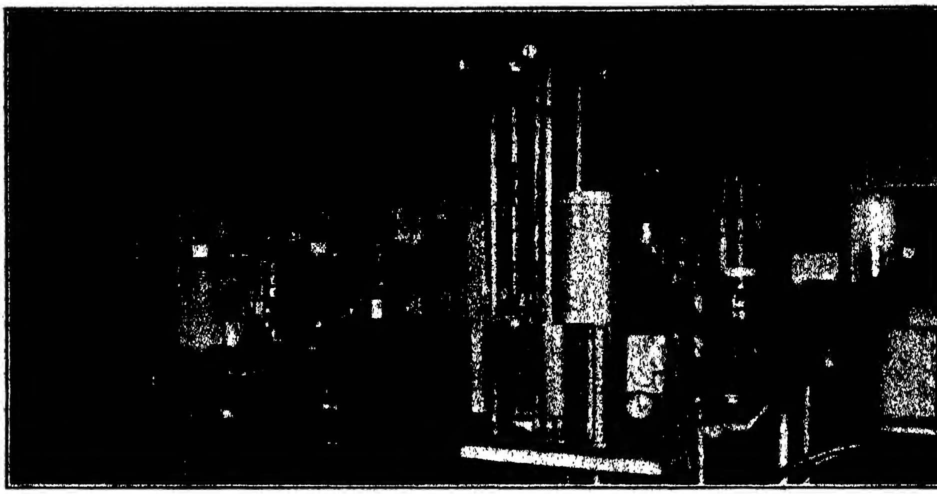
FOR KNOCK CHARACTERISTICS IN NEW STANDARD CAR ENGINE.

THE RATE OF WEATHERING

APPARATUS FOR ACCELERATED DETERMINATION OF THE RATE OF WEATHERING OF PROTECTIVE COATINGS SUCH AS PAINTS. THE PAINT FILMS ARE SUBJECTED TO WATER SPRAY AND THE LIGHT OF AN ARC.

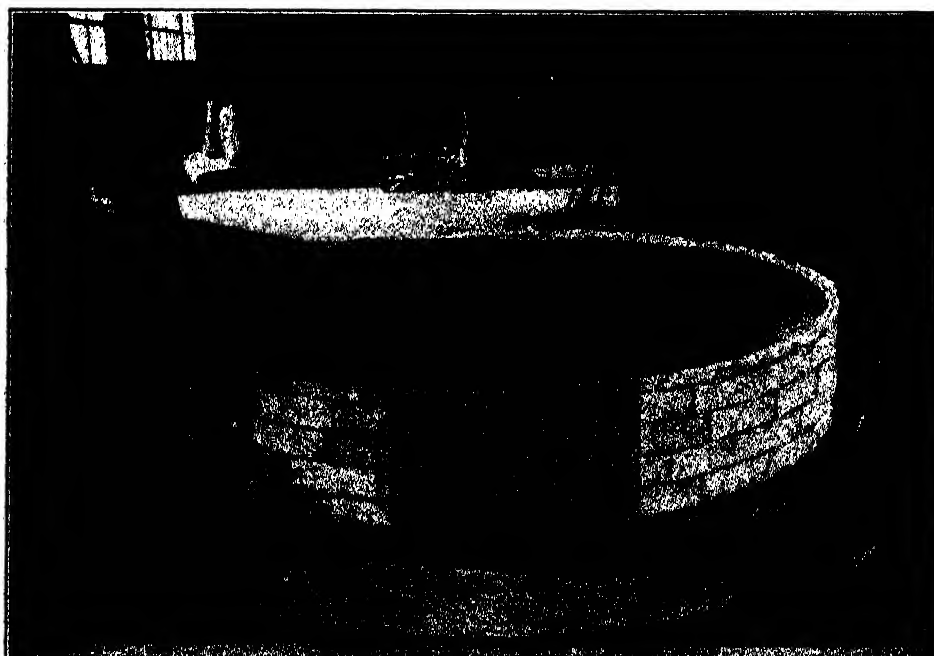
there are but three laboratories in the United States equipped to make such tests as a routine matter. In about two years an undetermined property of cement became one of paramount interest for certain purposes.

Even though attention may have been called to it in previous articles in this series, the Bureau's work in the testing and certification of instruments used in industry should be mentioned. Practically all measurements in all industries are made with devices whose calibrations are based upon the fundamental standards maintained according to the Federal law at the Bureau. In many cases the actual calibration and certification has been carried out at the Bureau. In the majority of cases this has been done at the plant producing the device through comparison with standards received from the Bureau. Included in such apparatus are thermometers, pyrometers, scales, balances, weights, volumetric equipment, the many kinds of electrical measuring devices, proving rings for calibrating large capacity testing machines, cement of certain fineness for calibrating cement testing sieves,



MEASURING LATENT AND SPECIFIC HEATS OF WATER

SOME OF THE APPARATUS USED IN A DIRECT MEASUREMENT OF THE LATENT AND SPECIFIC HEATS OF WATER AND THE SPECIFIC HEAT OF SUPERHEATED STEAM AT HIGH TEMPERATURES.

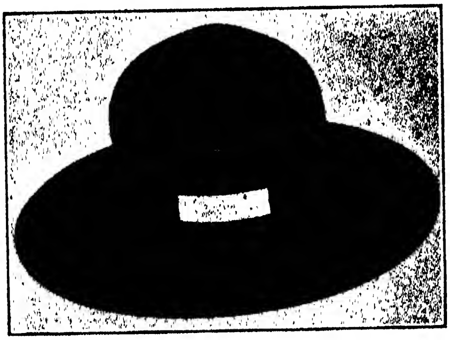


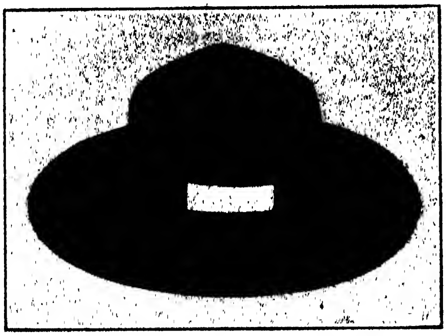
GLASS DISK FOR ASTRONOMICAL REFLECTOR

THE LARGEST ONE EVER CAST IN THE UNITED STATES IS SHOWN AT THE BUREAU OF STANDARDS IMMEDIATELY AFTER REMOVAL FROM THE MOLD IN WHICH IT WAS CAST. THE MOLD WAS MADE OF SOFT REFRACTORY INSULATING BRICKS, WHICH HAVE LEFT THEIR IMPRINT ON THE SIDE OF THE DISK. THE LENS STILL RESTS ON THE BRICK, WHICH CAN ALSO BE SEEN THROUGH IT. IN THE BACKGROUND IS THE FURNACE CONTAINING THE POT IN WHICH THE GLASS WAS MELTED, AND IMMEDIATELY IN FRONT OF IT THE PIT IN WHICH IT WAS ANNEALED.

pure metals and pure chemicals for use in calibrating pyrometers, calorimeters, standard solutions, etc. This kind of work is of absolute necessity in the production and sale of industrial materials.

The Bureau has at all times a very considerable percentage of its staff engaged in making tests of commodities, delivered to the various Federal Government purchasing agencies, to determine

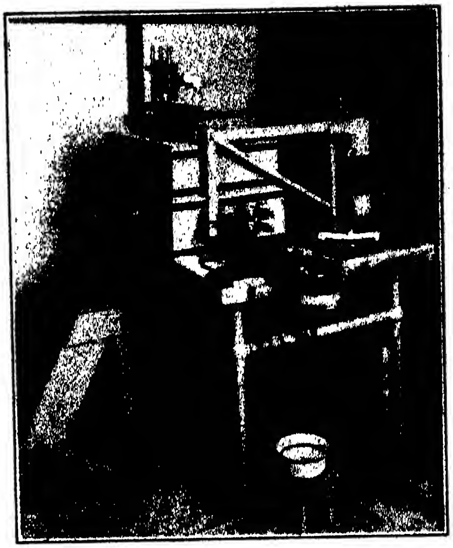




THE ALL AMERICAN HAT

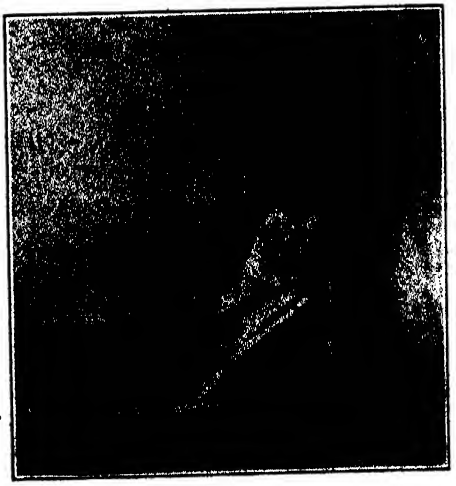
THE REGULAR SERVICE HAT (TOP) IS TREATED WITH IMPORTED SHELLAC TO GIVE IT THE DESIRED STIFFNESS. THE LOWER ONE IS TREATED WITH A SYNTHETIC GUM MADE IN THE UNITED STATES FROM COAL, WATER AND LIMESTONE. BOTH HATS HAVE BEEN THROUGH FIVE MONTHS OF ACTIVE SERVICE AT FORT BENNING.

whether or not they meet the requirements of the specifications under which they were bought. While these tests are largely concerned with all the materials commonly used in construction, particu-



TESTING FIRE BRICK

SOME INDUSTRIAL MATERIALS ARE USED ONLY AT HIGH TEMPERATURES AND UNDER LOAD. THE APPARATUS ABOVE IS USED TO DETERMINE THE DEFLECTION UNDER ANY APPLIED LOAD OF FIRE BRICK AND OTHER REFRACTORIES AT TEMPERATURES UP TO 1250° C. THE WHITE BAR TOWARDS THE RIGHT EDGE OF THE TABLE SHOWS A SPECIMEN CUT FROM A FIRE BRICK AFTER A TEST.



THE GLARIMETER

DOES THE GLARE FROM THIS PAPER HURT YOUR EYES? THE APPARATUS SHOWN ABOVE IS USED TO MEASURE THIS PROPERTY OF PAPER.

DETERMINING WEAR OF RUGS

THIS DEVICE HAS A LEATHER SHOE SURFACE FOR ABRADING THE RUG AND A VACUUM CLEANER FOR REMOVING THE ABRADED MATERIAL. A WORN SAMPLE IS SHOWN ON THE FLOOR BENEATH THE MACHINE.

larly of buildings, there is much time spent also in testing oils, gasoline, textiles, paper, leather, rubber, etc. This work is invariably supplemented with research interesting to producers, especially looking towards the proper use of commodities and the further development of the more desirable properties. The results are applied in the drawing up of specifications and their revision in connection with the Federal Specifications Board. In a later paper of this series attention will be directed towards showing how such specifications are brought to the notice of manufacturers to ascertain if they desire to be listed as suppliers of materials guaranteed by them to comply with the requirements of the federal specifications. This latter paper will present the work being done in aiding industries in eliminating excess sizes and varieties of various materials and establishing standards covering grades, quality, dimensional interchangeability or other acceptance criteria. The findings of the industries, including distributors and consumers as well as producers, are issued by the Bureau of Standards as "Simplified Practice Recommendations and Commercial Standards."

These efforts of the Bureau in connection with the preparation of specifications and the testing of government purchases of materials, so far as industrial materials are concerned, are most important ones. They serve particularly to bring the members of the staff working on the various commodities in direct contact with both producers and users. The staff thus obtains the view-point of both interested groups, realizes the limitations of the products as presented by the maker and the user, and serves to temper too severe service demands to

DEVICE FOR TESTING TABLEWARE

TABLEWARE, AS WE ALL KNOW, WILL BREAK AND CHIP AT THE EDGES. THE GOVERNMENT BUYS THE WARE FOR ITS BARRACKS, HOSPITALS, ETC., ON SPECIFICATIONS REQUIRING THAT IT SHALL NOT BREAK OR CHIP UNDER AN IMPACT OF LESS THAN A CERTAIN NUMBER OF FOOT POUNDS. THE ABOVE DEVICE IS USED FOR SUCH TESTING PURPOSES. NOTE THE PENDULUM WHICH CAN BE RELEASED AT CERTAIN POINTS ON THE STEEL ARC, GRADUATED IN FOOT POUNDS, TO DELIVER THE BLOW.

meet the production possibilities. At the same time it indicates how products may be modified so as to yield a commodity more nearly meeting service demands. The constant testing keeps information at hand showing when commodities have obtained qualities that will yield better or wider service through production refinements. This is passed on to interested users. The testing also at times may show the reverse, then just as properly the information is passed to the producers.

In many cases the specifications prepared through the Bureau's efforts have been developed only through intensive study. It is necessary at times to determine whether materials can be improved sufficiently to meet the increased service demands. This can be done by possibly making the product in question in one of the Bureau's mills. If the results are positive, the information is given to the interested industry which can apply them commercially. If negative, the user realizes his demands are excessive and he must either use what he has been accustomed to or turn to some other type of product.

Industrial materials, to be a live part of present-day commercial activities, must conform to certain standards of quality and standards of performance. These in turn must be based upon various standards of measurement and standard constants. Hence, it is quite evident why the Bureau, through its interest in fundamental standards and constants, also has through their application such a wide interest in the products of industry. It also indicates why the general public has come to rely so much upon the Bureau's work in this field.

BUILDINGS FOR THE PHYSICAL SCIENCES AT THE UNIVERSITY OF CHICAGO

THE BLOCK-LONG LINE OF SCIENTIFIC LABORATORIES, DEVOTED TO DISCOVERING THE SECRETS OF THE ATOM AND THE MOLECULE. IN THESE FOUR STRUCTURES, FACING THE MAIN QUADRANGLE AT THE UNIVERSITY OF CHICAGO, ARE THE LABORATORIES OF MANY OF THE COUNTRY'S LEADING PHYSICISTS AND CHEMISTS. IN THE FOREGROUND IS THE NEW BERNARD A. ECKHART HALL; SECOND IS RYERSON PHYSICAL LABORATORY, SEAT OF RESEARCH FOR AMERICA'S THREE WINNERS OF THE NOBEL PRIZE IN PHYSICS, MICHELSON, MILLIKAN AND COMPTON; THIRD IS KENT CHEMICAL LABORATORY; AND FACING THE END OF THE WALK, THE NEW GEORGE HERBERT JONES LABORATORY.

# THE PROGRESS OF SCIENCE

## THE FOURTH CHICAGO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

GREAT has been the change in the American attitude toward science during the past hundred years. A century ago we had perhaps the least general interest in science of any of the larger countries. But now we have the most. Applied science in many different forms has now become more wide-spread with us than with any other people, and our population as a whole takes more interest in science than does the population of any other country.

This interest in science—especially in applied science—in the country as a whole was largely the result of the solution of the problems, engineering, agricultural, geological and others, arising from the development of our Middle West and West, in the region, therefore, of which Chicago is the central city.

So it was most appropriate that the association should join with the Century of Progress in laying before all classes of our people the scientific achievements of the past hundred years in this and other countries.

An outstanding feature of the Chicago meeting was the presence of about thirty guests from foreign countries, who joined with the members of the association in reviewing the recent development of science and in presenting the latest information on a broad range of scientific subjects.

It is a rare privilege to be able to learn directly of their work from our foreign colleagues, and to be able to meet personally those whose achievements are so well known throughout the scientific world.

On the first evening of the meeting the president and the board of trustees of the Century of Progress gave a reception in honor of the association and its associated and affiliated societies and foreign guests. This reception was held in the Hall of Science.

Perhaps the leading feature of the Chicago meeting was the large number of joint sessions and symposia and their unusual interest. Among these may be mentioned the symposia on the measurement of geologic time, on colloid chemistry related to biological problems, on the application of quantum mechanics in chemistry, on spectroscopy and astrophysics and on isotopes. Of more popular interest were the symposia on a century of progress in medicine, nationalism, social trends, government policies during a depression and education in a democracy.

Worthy of special mention was a general session under the auspices of Section B (Physics) and Section C (Chemistry) held on Wednesday evening at Northwestern University with Niels Bohr presiding, at which F. W. Aston outlined the story of isotopes and R. A. Millikan spoke on new light on nuclear physics. All three of these gentlemen have received the Nobel prize for outstanding work in physics or in chemistry.

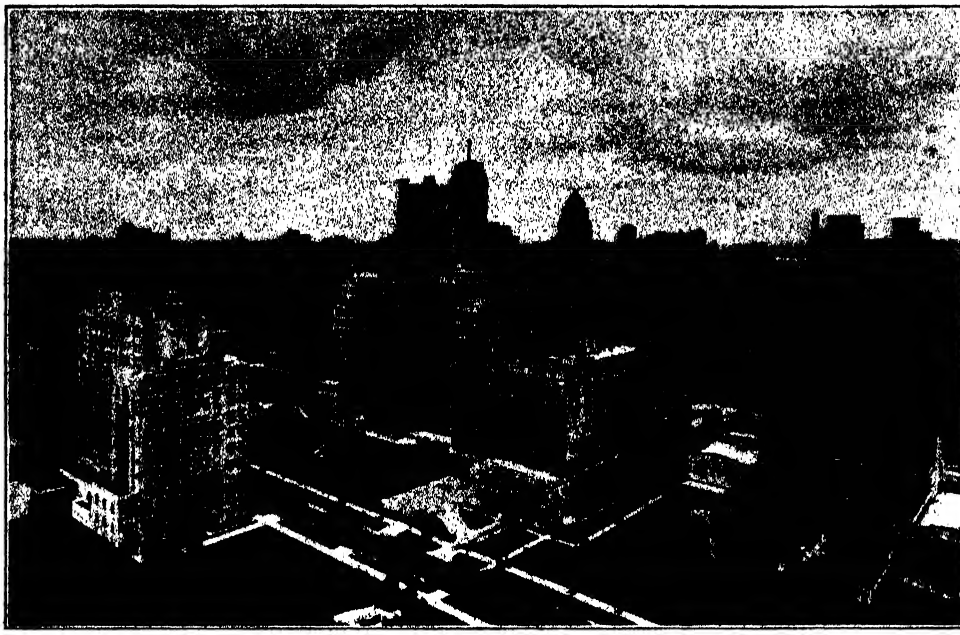
The program for the Chicago meeting was unusual in that the four founder engineering societies, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Civil Engineers, met with the association. Meeting with these were the American Society for Testing Materials, the American Ceramic Society, the Institute of Radio Engineers, the Western Society of Engineers, the American Society of Refrigerating Engineers, the Society for the

Promotion of Engineering Education, the American Foundrymen's Association, the American Association of Engineers, the Society of Industrial Engineers, and the National Council of State Boards of Engineering Examiners. Under the auspices of the Society for Testing Materials came the eighth Edgar Marburg lecture, by Herbert John Gough, of the National Physical Laboratory, England, who spoke on crystalline structure in relation to failure of metals, especially by fatigue.

In connection with the engineering meetings there were a number of important conferences, among which may be mentioned a symposium on some fundamental problems of mutual interest to scientific economists and engineers, a conference on English, a conference on cooperative engineering education, symposia on alloys in steel castings, on cast iron, and on deoxidation and degasification of bronze foundry alloys, and a foundry housekeeping conference.

A most delightful and memorable event in connection with the meeting was the banquet given at the Hotel Stevens on Thursday, June 22, in honor of the foreign guests—Otto Appel (Agriculture), Berlin; F. W. Aston (Chemistry), Cambridge; Joseph Barcroft (Physiology), Cambridge; A. Mendelssohn Bartholdy (Political Science), Hamburg; Jakob Bjerknes (Meteorology), Bergen; Niels Bohr (Physics), Copenhagen; Filippo Bottazzi (Physiology), Naples; Ludwig Diels (Botany), Berlin; Jean Dufrénoy (Agriculture), France; Leopold Fejér (Mathematics), Budapest; Enrico Fermi (Physics), Rome; A. P. M. Fleming (Engineering), Manchester; R. Goldschmidt (Zoology), Berlin; Herbert J. Gough (Engineering), London; Sir Daniel Hall (Agriculture), London; A. V. Hill (Physiology and Medicine), London; C. U. A. Kappers (Anthropology and Physiology), Amsterdam; Wolfgang Koehler (Psychology), Berlin; August Krogh (Zoology), Copenhagen; Tullio Levi-Civita (Mathematics), Rome; Emilio Mira (Psychology), Barcelona; William Oualid (Political Economy), Paris; Henri Piéron (Psychology), Paris; J. J. Sederholm (Geology), Helsingfors; Charles E. Spearman (Psychology), London; T. Svedberg (Chemistry), Upsala; and R. J. Tillyard (Entomology and Paleontology), Can-

THE YERKES OBSERVATORY AT WILLIAMS BAY, WISCONSIN



THE McKINLOCK CAMPUS AT NORTHWESTERN UNIVERSITY

The building shown at the extreme left is Passavant Hospital; directly across from it is the Medical School building.

berra. The president of the association, Dr. John Jacob Abel, presided, and the toastmaster was Dr. R. A. Millikan. The speakers were Rufus C. Dawes, Hugo F. Simon, Filippo Bottazzi, Henri Piéron, Jakob Bjerknes, Wolfgang Koehler, Sir Daniel Hall and Edwin B. Wilson.

All the scientific establishments and institutions in Chicago deserve the grateful thanks of the members of the association for their numerous courtesies, which contributed so much toward making the meeting one long to be remembered.

Through the local committee many interesting excursions were arranged. Among these were trips to the famous Indiana Dunes, to "Wychwood," at Lake Geneva, Wisconsin, to the Yerkes Observatory, at Williams Bay, Wisconsin, and to the Stock Yards.

Elaborate provision was made for the entertainment of the ladies of the association, including visits to the Lakeside Press, Hull House, the Chicago Women's Club, Northwestern University, North Shore private gardens, Jackson Park and the University of Chicago. Mr. Leon Mantel, III, was so very kind as to tender the use of his yacht *The Buccaneer* for a cruise along the shores of Lake Michigan.

Chicago in itself is an unusually interesting city. It is the birthplace of the skyscraper, America's foremost contribution to architecture. As its buildings have grown higher, its streets have been widened—its growth has not been entirely haphazard. Burnham's admonition, "Make no little plans," has been followed literally. The park and boulevard systems, the forest preserves, the reversal of the Chicago River as an item toward the sanitation of the city, and the development of the Lakes-to-Gulf Waterway are all integral parts of the plan.

Chicago as a city well exemplifies the spirit of America; scientifically it is

DR. PHILIP FOX AND DR. C. U. A. KAPPERS

DR. KAPPERS, THE DISTINGUISHED ANTHROPOLOGIST FROM HOLLAND, STANDING WITH THE DIRECTOR OF THE ADLER PLANETARIUM IN CHICAGO.

THE MUSEUM OF SCIENCE AND INDUSTRY AT CHICAGO

preeminent as a center for that type of science that is peculiarly American. This American type of science, having as its aim utilitarian advance rather than philosophical refinement, was appropriately emphasized by the cooperation between the association and the Century of Progress.

The success of any meeting depends chiefly on the ability and energy of those who bear the brunt of making the local arrangements and looking after the multitudinous and aggravating details that inevitably arise. Fortunate it was for the association that the local arrangements were in the hands of such an able and energetic organizer as Colonel Philip Fox, who, ably assisted by Rufus C. Dawes, Roy K. Marshall, D. R. Curtiss, Andrew M. MacMahon, Walter Bartky, John R. Ball, Henry Crew and others, deserves the association's most grateful thanks.

AUSTIN H. CLARK

NOBEL PRIZE WINNERS IN PHYSICS AT THE AMERICAN ASSOCIATION MEETING

PROFESSOR F. W. ASTON, UNIVERSITY OF CAMBRIDGE; PROFESSOR A. H. COMPTON, UNIVERSITY OF CHICAGO; PROFESSOR NIELS BOHR, UNIVERSITY OF COPENHAGEN.

LAZARE NICHOLAS MARGUÉRITE CARNOT[1]

One hundred and ten years ago this month, on August 2, 1823, there died in exile in Magdeburg one of the most remarkable men of one of the most remarkable centuries in the history of France—Carnot, "l' Organizateur de la Victoire." Soldier, administrator, mathematician, physicist, new master in the construction of fortifications, the patriot who dared oppose the ambitions of Napoleon and who, when France called him, returned to the imperial standard in the fatal Hundred Days—this is the man to whom Bonaparte addressed these words after the defeat at Waterloo, "Carnot, je vous ai connu trop tard!"

Born at Nolay, Côte-d'Or, on May 13, 1753—one of a family of eighteen children, of which two developed into lieutenant generals, one became a councilor in the Cour de cassation, one a Procureur général of the Royal Court, another a directress of the hospice at Nolay—he came of good stock. In return he passed on the vigor of his clan;

[1] The medallion reproduced on this page is by David D'Angers and is in the Smith Collection in the Library of Columbia University.

for his eldest son, Nicholas Léonhard Sadi Carnot (1796–1832), was a physicist, author of the "Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance" (Paris, 1824), and was one of the first to comprehend the nature of heat as recognized by later scientists. The second son, Lazare Hippolyte (1801–1888), was one of the leaders in the movement for popular education. A grandson (son of Lazare Hippolyte), Marie François Sadi Carnot (1837–1894), became the fourth president of the Republic, fought for his country and, like his distinguished ancestor, now rests in the Panthéon, the Valhalla of France.

Educated in the Collège d' Autun and the École de Mézières, coming under the influence of D'Alembert and Bossut, he entered the army and here he made his early reputation both in the line of physics and in his work in the field of fortifications. The old system of defense, due to Vauban, was by him replaced by an improvement upon Montalembert's plan for the construction of forts, and his memoirs on the subject, following his "Éloge de Vaubàn" (1783), were looked upon as authorities for a full century after they appeared. His chief work on the theory was "De la défense de places fortes" (Paris, 1810). In his early days as a first lieutenant at Calais he also gave much attention to the subject of dirigible balloons, and his first communication to the Académie des Sciences was on "Le problème de la direction des aérostats." Although this was more than a century before dirigibles met with any notable success, he never lost confidence in the possibility of this mode of travel.

In 1783 he wrote his "Essai sur les machines en général," and twenty years later there appeared his "Principes fondamentaux de l' équilibre" (Paris, 1803), but he is chiefly known for his military achievements and his contributions to geometry. For training in the first of these fields the French Revolution supplied abundant opportunity. The members of the *Comité de salut public* (1793) were chosen by the convention, and Carnot was one of the most active, being charged with the organization of the armies, a position that challenged to the limit his scientific abilities. Copper was lacking for the guns, and he seized the bells of churches and convents; saltpeter was lacking, and he called chemistry to his aid; leather was needed for boots, and he demanded and secured new methods of tanning; guns must be had, and his knowledge of mechanics created them; the army was inefficient, and in a single year he organized fourteen armies; rapid communication amongst these armies was essential, and he helped perfect a new system of signals; reconnaissance of the enemy's positions was crude, and he used balloons.

In scientific circles, however, he will be known the best for his contributions to geometry. The "De la corrélation des figures de géométrie" (Paris, 1801) laid one of the corner-stones of the modern treatment of the subject, extended to three dimensions in his "Mémoire sur la Relation qui existe entre les distances respective de cinq points quelconques pris dans l' espace; suivi d' un Essai sur la Théorie des Transversales" (Paris, 1806). These were preceded by his "Réflexions sur la métaphysique du calcul infinitésimal" (Paris, 1797), in which he supported the Leibnitzian calculus and paved the way for Cauchy's notable memoir and for the elimination of the objections which Dean Berkeley (later Bishop of Cloyne) raised more than a half century earlier.

Mention should also be made of his assistance in the creation of two of the greatest schools of the world, the *École normale supérieure* and the *École polytechnique*, of the *Conservatoire des arts et métiers*—freedom's answer to the charge that the revolutionists were the children of ignorance and brutality.

David Eugene Smith

## BALL LIGHTNING

ONE of the most difficult phenomena in nature to study is that known as ball lightning. It is so rare that comparatively few persons have ever seen it, and these observers have been so startled that they can not give a clear description of what they saw. Even a trained scientist would find extreme difficulty in making any worthwhile tests or measurements on a ball of blue fire as large as two fists which rolled along the floor for three or four seconds and then collapsed with a noise resembling a big firecracker, leaving behind nothing more tangible than the odor of ozone. Yet these are the salient points in the descriptions reported by C. F. Talman, of the U. S. Weather Bureau, in a recent popular article, also by E. W. Marchant and W. C. Reynolds in the 1930 volume of *Nature*.

During the thunderstorm seasons of 1929, 1930 and 1931, we have been engaged in a study of the electrical field changes caused by lightning discharges, with special reference to relation of the direction of branching of the flash to the sign of the field change. This involved photographing a large number of discharges at night, most of them at close range as the storm center approached or came directly overhead. The path of the storm centers was traced by means of a battery of microbarographs.[1]

On the evening of August 30, 1930, after a sultry day characterized by local thunderstorms in the surrounding territory to the south, a severe storm of the "line-squall" type developed in the west in the early evening. The wind had been scarcely perceptible from the southeast but changed to the southwest and increased to twenty or thirty miles per hour between 9:35 and 9:45. Rain, accompanied by high northwest winds, began at 9:53. The barograph record shown in Fig. 4 indicates an increase of .21 inches in pressure in the front of the storm, followed by an immediate rise of .06 inches when the active part of the storm, with its rapid convection currents, passed over the instrument. The time on this record is about twenty minutes slow, as this rise began at 9:35.

For making the photographs two cameras were placed in a fourth-story window above the trees and commanding a clear view of the western horizon. One of these is a 5×7 Graflex with a lens rated at f 4.5, the other an Eastman 1A Kodak with f 6.3 lens.

[1] J. C. Jensen, *Monthly Weather Rev.*, Vol. 58, p. 115, 1930; *Physical Rev.*, Vol. 40, p. 1013, 1932.

FIG. 1.

The cold air rushing ahead of the nimbus cloud was filled with a swirling mass of dust, but nevertheless brilliant flashes were seen descending in rapid succession from the cloud to the earth when the first films were exposed at 9:40 P. M. In the wake of one of these flashes there appeared a shapeless mass of lavender color which seemed to float slowly downwards. The writer was so occupied with the details of the photographic routine, which required the operation of shutters, the use of a stop-watch for timing the lightning-thunder interval, entering data in the note-book and telephoning to the assistant who had charge of the electrical recording apparatus in the laboratory, that there was little opportunity for close observation of this beautiful but unexpected display. The rose-colored mass seemed most brilliant near the ground and gave the impression of a gigantic pyrotechnic exhibition. Two or three of the globular structures seemed to roll along a

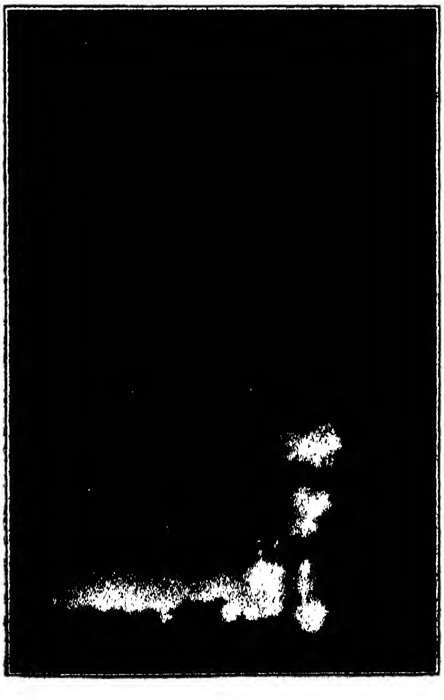


FIG. 2.

FIG. 3.

pair of 2,300 volt power lines for 100 feet or more, then bounce down on the ground and disappear with a loud report.

The first five pictures, covering an interval of about three minutes, all show the fire-balls in one of their stages. Fig. 2 is an enlargement of the first Graflex picture at 9:40 P. M. The one caught at the same instant with the kodak resembles it closely, the lightning streamers in the rear being identical. Fig. 1 is a direct contact print from the second Graflex negative. It shows the principal descending ball in its most luminous and concentrated form. Although the shutter was open for only a few seconds, two brilliant lightning discharges appear in the background. The one in the center with streamers extending downward gave a field change which indicated that

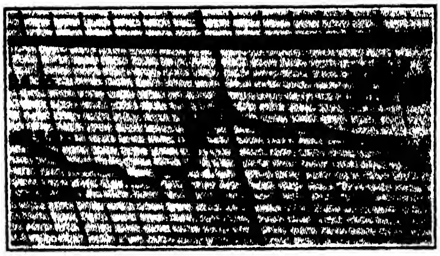


FIG. 4.

negative electricity had escaped from the cloud to earth. The kodak shutter was closed while Fig. 1 was being taken, but both cameras caught the final stage as shown in the enlargement of Fig. 3. The kodak lens was left open longer and shows less detail, together with blurring, due to motion of the illuminated balls.

As mentioned above, some of the fire-balls bounced off a power-line which was about 2,000 feet from the observer. Using the well-known optical formula relating the size of the object and the image to the object distance and focal length of the lens, the diameter of the first upper ball in Fig. 2 is shown to be 28 feet and that in Fig. 1, 42 feet. Their height above the horizon was 92 feet. It will be objected that these dimensions are so much larger than the conventional size that they must relate to different phenomena. However, Toepler[2] states the "masses of light" may vary in size from a hen's egg to 10 meters in diameter, and on another occasion during the course of our researches balls of similar magnitude were seen at a distance of two and one half miles but no photographic record was obtained. In this case also the balls collapsed with a sharp, loud report.

A tornado which occurred on the evening of July 9, 1932, near Rock Rapids, Iowa, gave evidence of a closely related type of luminous display, according to the report of Mr. George Raveling, U. S. Weather Bureau observer. From the sides of the boiling, dust-laden cloud a fiery stream poured out like water through a sieve, breaking into spheres of irregular shape as they descended. No streak lightning of the usual type was observed and no noise attended the fire-balls other than the usual roar of the storm.

While it is not the purpose of this article to propose a scientific explanation to account for the facts here related, meteorologists will find valuable material for study in the references given below.[3] Any of our readers who have witnessed these interesting phenomena are requested to send detailed reports to the author of this article.

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[2] Max Toepler, *Mitteil. d. Hermsdorf Schomburg Isolatoren,* Vol. 25, p. 18, 1926.

[3] Max Toepler, *Ann. d. Physik,* Vol. 4, sec. series, p. 623, 1900; Cawood and Patterson, *Nature,* Vol. 128, p. 150, 1931; W. C. Reynolds, *ibid.,* p. 584; also Vol. 126, p. 413, 1930; Mathias, *Comp. Rend.,* Vol. 194, p. 413, 1932; *ibid.,* p. 2257.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1933

# THE CALAKMUL EXPEDITION[1]

By Dr. SYLVANUS G. MORLEY

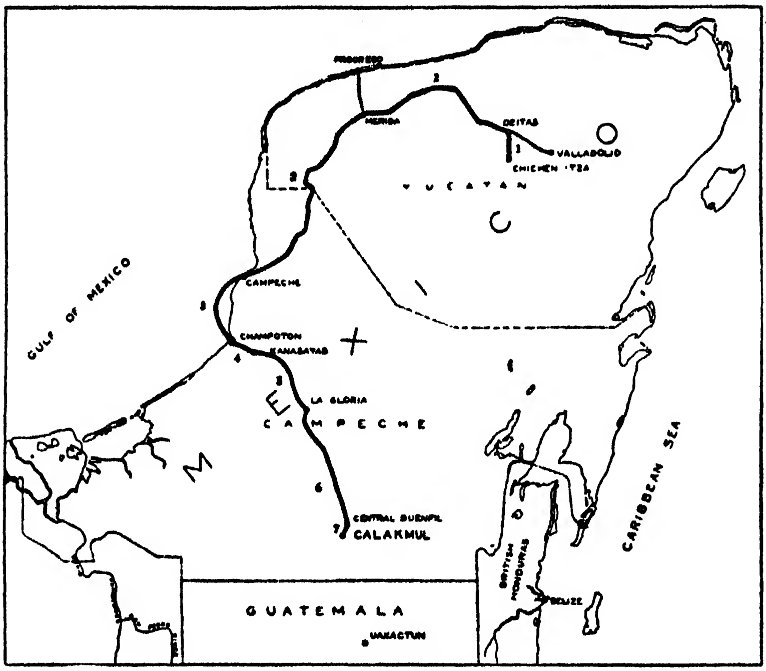
ARCHEOLOGIST OF CARNEGIE INSTITUTION OF WASHINGTON

THE expedition reached Campeche on April 5, where Mr. J. C. Brydon, manager of the Mexican Exploitation Company, met the party. The equipment and supplies had been forwarded to San Dimas, a station on the tram-line between Kanasayab and La Gloria, several days in advance. Mr. Brydon had also engaged two automobiles to take the party the next lap of the journey to the hacienda of San Dimas, 55 miles distant. After an eight-hour drive, the latter part over an all but impassable wood road through the forest, the expedition reached San Dimas at eleven o'clock the same night, where it was most hospitably received by Mr. Sanchez, local manager of the Montana Company, and quartered at the hacienda house.

The next lap of the journey was made over a Deceauville tram on small platform cars, ten feet long, drawn by two mules tandem without reins, the mules being attached to the platform by a single pair of traces. At four o'clock on the afternoon of April 6, the expedition reached La Gloria, the chicle station of Don Francisco Buenfil.

Don Francisco Buenfil, of Merida and Campeche, is the largest private chicle operator in the state of Campeche. He had visited Chichen Itzá earlier in the 1932 season and when he learned of the Institution's contemplated expedition to Calakmul had generously placed the facilities of his organization at its service. Occasion should be taken here to state that the success of the Calakmul expedition was due in large measure to the generous assistance received from

[1] Dr. Sylvanus G. Morley, archeologist in charge of the field work in Yucatan for Carnegie Institution of Washington, headed an expedition, which was sent into an uninhabited part of southern Campeche for the purpose of examining the ruins of an ancient Maya city, discovered a few months before by Mr. C. L. Lundell, an employee of a chicle company operating in the region. When on a scouting trip for his company, Lundell, on December 29, 1931, came upon jungle-covered ruins to which he gave the name "Calakmul," which means, in the Maya tongue, "two adjoining mounds," a name having significance, as Lundell thought, because the two highest pyramids, each about 150 feet in height, stood close together. Lundell took photographs and made a sketch map of the site. A little later, these came into the hands of Dr. Morley, who identified the ruins as being those of an Old Empire City which had been built to the north of the known limits of the Old Empire region. Because of its location so far north, Morley believed the ruins to be of sufficient scientific importance to justify the organization of an expedition to visit it and to make a thorough study of its principal features. Obtaining approval of his plan from the Mexican government and from Carnegie Institution, the expedition left field headquarters at Chichen Itzá, Yucatan, Mexico, on April 3, 1932. Its personnel consisted of Dr. Morley, director, Karl Ruppert, archeologist, J. S. Bolles, architect and surveyor, Gustav Stromsvik, engineer, Mrs. Morley, in charge of the commissary, and two camp assistants. Dr. Morley here gives an account of the journey and of the results obtained.




MAP OF YUCATAN

SHOWING LOCATION OF NEWLY DISCOVERED CITY OF CALAKMUL, SOUTHERN CAMPECHE, MEXICO. HEAVY BLACK LINE INDICATES ROUTE FOLLOWED BY CARNEGIE INSTITUTION OF WASHINGTON EXPEDITION FROM CHICHEN ITZÁ TO CALAKMUL.

the members of Mr. Buenfil's efficient organization at all stopping places from Campeche to Calakmul.

The journey beyond La Gloria was made in a five-ton truck over chicle trails that are utterly impassable for motor transport during the rainy season, and not much better during the dry season. The stretch from La Gloria to Central Buenfil, a distance of 70 miles, was covered in 27 consecutive hours, including eight hours out for sleep in the midst of the forest.

The expedition left La Gloria at 3:15 on the afternoon of April 7 and reached Central Buenfil at 6:15 the following afternoon, after a nerve-racking, muscle-beating journey. The truck-pass over the hills was narrow, the truck scraping the bushes and trees on either side and breaking off the lower branches as it lumbered along.

In the *akalches*, or swamps, the lower bush is cleared to a width of about 100 feet so that the sun may reach these marshy places. Although these marshes were nearly dry at the time the expedition passed through them, several bogs were traversed which necessitated chaining short logs to the rear wheels to provide sufficient traction in the bottomless mud.

The expedition was cordially received at Central Buenfil by Don Manuel Osorno, the general manager, and arrangements were made with him for mules to transport the party and outfit the remaining seven miles south to the ruins of Calakmul.

Thirty mules, including pack animals, were required to transport the personnel and outfit from Central Buenfil to Calakmul. Fifteen laborers were employed during the fifteen days' stay at

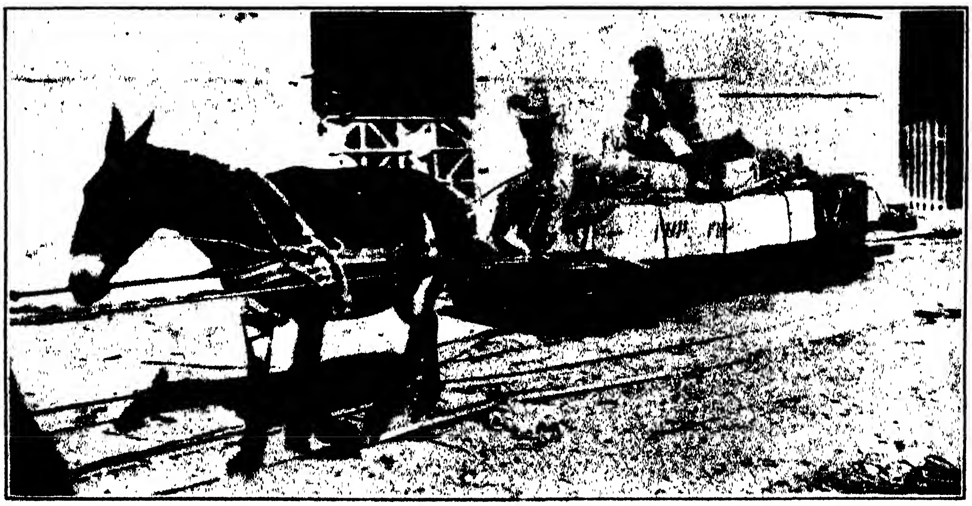
the site (April 9–24) and two camp cooks.

The first afternoon (April 9) was devoted to making camp, putting up tent covers for sleeping quarters and mess hall, building a kitchen stove and table, and arranging the outfit, supplies, saddles, tools, etc.

The following day was one of the most remarkable in the writer's twenty-five years of tropical exploration. With the Lundell sketch map as a guide, the institution party set out to explore the area covered by the map. Lundell had enumerated 64 stelae, or sculptured hieroglyphic monuments, of which the expedition was able to find all but two. One of the missing two was the unsculptured rectangular altar on the summit of the substructure supporting the middle building of Structure D, which Lundell had mistaken for a sculptured stela; the other was not found in the position indicated on his sketch map and it appears probable that he must have confused it with some other stela already accounted for elsewhere. This reduced the total of stelae found by Lundell to 62.

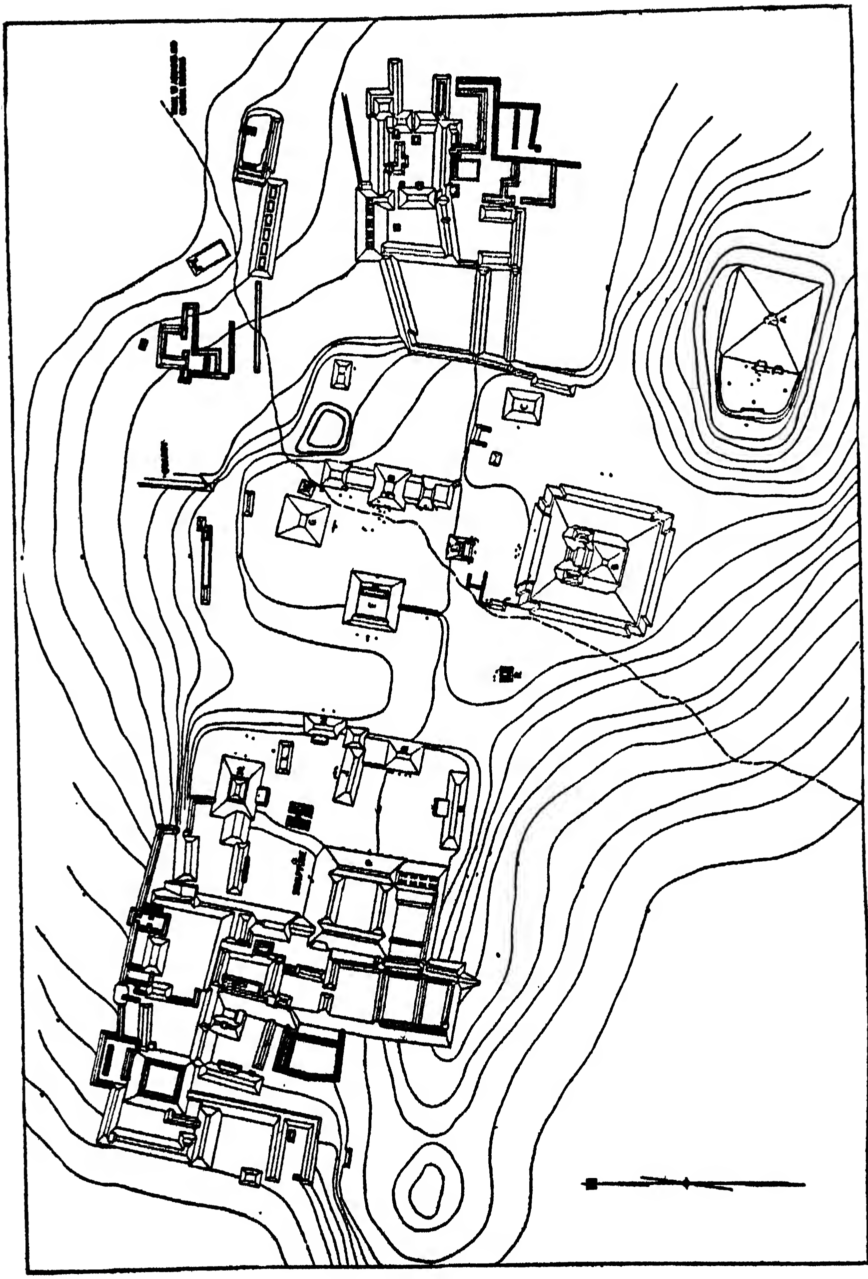
The Carnegie Institution's Calakmul expedition, during the 15 days it was at the site, discovered 41 additional stelae, bringing the total of known stelae at this site to 103, the largest number by 27 per cent. yet reported from any other city of the Maya civilization. The nearest competitor to Calakmul in this respect is Tikal in northern Guatemala, which contains a total of 75 stelae, of which, however, only 18 (*i.e.*, less than 25 per cent.) are sculptured. The Old Empire site having the largest number of sculptured stelae previously reported is Piedras Negras in northeastern Guatemala with a total of 45.

Calakmul, on the other hand, has at least 74 surely sculptured stelae, and of the remaining 29 it is practically certain that another half dozen originally had been sculptured, although their carving has entirely disappeared owing to the softness of the limestone which was used and the excessive weathering to which the stelae have been subjected. It is therefore hardly an exaggeration to say that originally Calakmul probably had almost twice as many sculptured



PLATFORM CAR DRAWN BY TWO MULES, TANDEM

USED IN HAULING OUT BLOCKS OF CHICLE (CRUDE CHEWING GUM) FROM THE INTERIOR. THE CALAKMUL EXPEDITION PERSONNEL AND BAGGAGE TRAVELED FOR FIFTY MILES ON THESE PLATFORM CARS.



MAP OF THE CIVIC AND RELIGIOUS CENTER OF CALAKMUL

SURVEYED AND DRAWN BY MR. J. S. BOLLES. THE PRINCIPAL STRUCTURES ARE DESIGNATED BY LETTERS; THE MONUMENTS ARE REPRESENTED BY SMALL BLACK RECTANGLES. NOTE THAT THE AREA BOUNDED BY STRUCTURES D, E, F, G, CONSTITUTES THE MAIN PLAZA OF THE CITY. IT WAS HERE THAT THE STAFF CAMP WAS ESTABLISHED.

THREE SCULPTURED STELAE

AT SOUTHWESTERN CORNER OF STRUCTURE E. THE MONUMENT AT THE RIGHT HAS A WILD FIG TREE GROWING ON TOP OF IT, THE ROOTS COVERING THE FRONT.

stelae as any other Maya site yet discovered.

The work of the expedition was divided as follows: The writer devoted his time to the epigraphy, assisted by Mr. Stromsvik who took entire charge of turning the heavy fallen monoliths, some weighing as much as five or six tons, many laying with their sculptured faces downward. Mrs. Morley took charge of the photography; Mr. Ruppert made a study of the architecture, though only one building, Structure C, was sufficiently preserved to allow a detailed ground-plan to be made of it without excavation. Mr. Bolles made a surveyed map of the center of the site, covering an area about three fifths of a mile long by about half a mile wide, and located the positions of all mounds and monuments thereupon. Bolles also determined the latitude of Calakmul as 18° 2′ N. and the longitude as about 89° 52′ W. Finally, in addition to his work in turning the fallen stelae, Mr. Stromsvik made a number of minor excavations looking for stratified deposits of potsherds; he also made a study of the small stone artifacts which were found, such as *metates*,[2] grinders, etc.

One of the most important results of the expedition was the discovery of no less than 51 Initial Series, the largest number of these amazingly accurate time-counts or dates ever found at any other Old Empire city except Copan in Honduras. Of this number it was possible to decipher the dates of 42, surely; of two more, probably; and of nine, more doubtfully. In addition to these 51 Initial Series, four Period-Ending dates were identified. In all, the dates of about half of the 103 stelae found at Calakmul may be said to have been correctly deciphered.

The dates of the Calakmul stelae, in so far as they have been deciphered, ar-

[2] The name generally applied to the stone slabs or blocks upon which the American Indian grinds his corn.

LIST OF DATES DECIPHERED AT CALAKMUL

| Monument | Date in Maya Chronology[1] | Date in Christian Chronology[2] | Kind of Date |
|---|---|---|---|
| Stela 43 | 9. 4. 0. 0. 0 | 254 A.D. | Initial Series |
| " 28 | 9. 9.10. 0. 0 | 364 " | " " |
| " 29 | 9. 9.10. 0. 0 | 364 " | " " |
| " 1 | 9.10. 0. ?. 5 | 373 " | " " |
| " 9 | 9.10.16.16.19 | 390 " | " " |
| " 32 | 9.11. 5. 0. 0(??) | 398 " | " " |
| " 33 | 9.11. 5. 0. 0(?) | 398 " | " " |
| " 35 | 9.11. 8.10. 8 | 402 " | " " |
| " 35[3] | 9.11.10. 0. 0 | 403 " | " " |
| " 36 | 9.11.10. 0. 0 | 403 " | " " |
| " 9 | 9.11.10. 0. 0 | 403 " | " " |
| " 9[4] | 9.12. 0. 0. 0 | 412 " | Period-Ending |
| " 13 | 9.12. 0. 0. 0 | 412 " | Initial Series |
| " 74 | 9.12. 0. 0. 0(??) | 412 " | " " |
| " 75 | 9.12. 0. 0. 0 | 412 " | " " |
| " 86 | 9.12. 0. 0. 0 | 412 " | " " |
| " 76 | 9.12. 5. 0. 0 | 418 " | " " |
| " 70 | 9.12. 8. 9. 9 | 421 " | " " |
| " 77 | 9.12.10. 0. 0(?) | 423 " | " " |
| " 93 | 9.12.10. 0. 0 | 423 " | " " |
| " 94 | 9.12.10. 0. 0 | 423 " | " " |
| " 79 | 9.13. 0. 0. 0(??) | 432 " | " " |
| " 23 | 9.13.10. 0. 0 | 442 " | " " |
| " 24 | 9.13.10. 0. 0 | 442 " | " " |
| " 38 | 9.13.10. 0. 0(??) | 442 " | " " |
| " 40 | 9.13.10. 0. 0 | 442 " | " " |
| " 41 | 9.13.10. 0. 0(??) | 442 " | " " |
| " 71 | 9.14. 0. 0. 0 | 452 " | " " |
| " 72 | 9.14. 0. 0. 0 | 452 " | " " |
| " 73 | 9.14. 0. 0. 0 | 452 " | " " |
| " 8 | 9.14.10. 0. 0 | 462 " | " " |
| " 46 | 9.14. ?. ?. ? | 462 " <br> 471 " | " " <br> " " |
| " 51 | 9.14.19. 5. 0 | 471 " | " " |
| " 52 | 9.15. 0. 0. 0 | 471 " | " " |
| " 53 | 9.15. 0. 0. 0 | 471 " | Period-Ending |
| " 54 | 9.15. 0. 0. 0 | 471 " | Initial Series |
| " 55 | 9.15. 0. 0. 0 | 471 " | " " |
| " 48 | 9.15. 0. 0. 0 | 471 " | " " |
| " 89 | 9.15. 0. 0.14 | 471 " | " " |
| " 26 | 9.15. 5. 0. 0 | 477 " | " " |
| " 25 | 9.15.10. 0. 0 | 482 " | " " |
| " 27 | 9.15.10. 0. 0 | 482 " | " " |
| " 59 | 9.15.10. 0. 0 | 482 " | " " |
| " 60 | 9.15.10. 0. 0(??) | 482 " | " " |
| " 62 | 9.16. 0. 0. 0 | 491 " | Period-Ending |
| " 57 | 9.17. 0. 0. 0 | 511 " | Initial Series |
| " 58 | 9.17. 0. 0. 0 | 511 " | " " |
| " 80 | 9.18. 0. 0. 0 | 530 " | " " |
| " 67 | 9.18.10. 0. 0 | 541 " | " " |
| " 69 | 9.18.10. 0. 0 | 541 " | " " |
| " 15 | 9.19. 0. 0. 0 | 550 " | Period-Ending |
| " 16 | 9.19. 0. 0. 0 | 550 " | Initial Series |
| " 64 | 9.19. 0. 0. 0(??) | 550 " | " " |
| " 39 | 9. ?. ?. ?. ? | ........ " | " " |
| " 45 | 9. ?.10. 0. 0 | ........ " | " " |

STELAE 28 AND 29, THE TWO OLDEST MONUMENTS AT CALAKMUL

THEY STAND ON THE NORTH SIDE OF STRUCTURE E AND WERE BOTH ERECTED ON THE SAME DAY, 9.9.10.0.0 IN THE MAYA CHRONOLOGY, WHICH CORRESPONDS TO 364 A.D. IN THE CHRISTIAN CHRONOLOGY, ACCORDING TO THE MORLEY-SPINDEN CORRELATION.

ranged in their chronological order, are given in the accompanying table; the name of the monument appears in the first column; the corresponding date in Maya chronology, in the second column; the corresponding equivalent in Christian chronology, according to the Morley-Spinden correlation, in the third column;[3] and the kind of date, *i.e.*, whether an Initial Series or a Period-Ending, in the fourth column. The corresponding terminal dates of these Initial Series and Period-Ending dates have been omitted for convenience in comparison. Doubtfully deciphered dates are marked with a single interrogation point and very doubtfully deciphered dates with two interrogation points.

[3] According to the Goodman-Martinez-Thompson correlation of Maya and Christian chronology the dates in the third column are 259 years later.

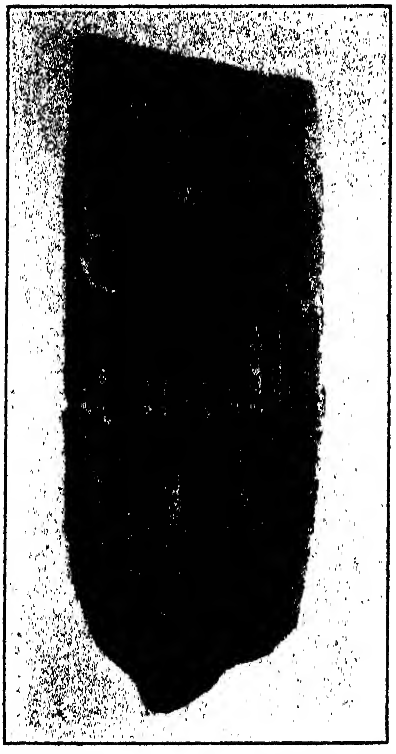
In the light of its sculptured monuments Calakmul stands revealed to us as a large, somewhat provincial city of Class 2, which reached the point of erecting sculptured stone monuments at the close of the Early Period (9.9.10.0.0) (see accompanying photograph) and continued the practise until toward the close of the Great Period (9.19.0.0.0) at which time this site seems to have been abandoned, or at least a stage in its social, governmental and economic disorganization had been reached when it

[1] As noted in the text, 9.4.0.0.0 probably is not the contemporaneous date of Stela 43 but a date perhaps as much as two centuries later.

[2] Morley-Spinden Correlation.

[3] Stela 35 has two Initial Series, though only the second, 9.11.10.0.0, records the contemporaneous date of this monument.

[4] Although Stela 9 has two Initial Series, the contemporaneous date of this monument is recorded by a Period-Ending date, 9.12.0.0.0.



THE MOST BEAUTIFUL MONUMENT AT CALAKMUL

IT IS LOCATED IN FRONT OF THE PYRAMID SUPPORTING STRUCTURE A. THIS STELA (STELA 51) BEARS A DATE WHICH CORRESPONDS TO 471 A.D., ACCORDING TO THE MORLEY-SPINDEN CORRELATION. WHEN DISCOVERED IT WAS LYING WITH ITS SCULPTURED FACE TO THE GROUND WHICH ACCOUNTS FOR ITS EXCELLENT STATE OF PRESERVATION.

was no longer able to erect stone monuments of any kind, either sculptured or unsculptured.

The dates on the Calakmul stelae indicate that the inhabitants of this ancient city marked the ends of the successive five-year periods of the Long Count —the *hotuns*—not only by the erection of a single sculptured monument, as was usually the case, but occasionally, particularly on the *lahuntun* and *katun*-endings (*i.e.,* the ends of the 10- and 20-year periods successively) by the erection of two, three, four and in one case (9.15.0.0.0) even seven different monuments, one of which, Stela 51, is shown.

No other city of the Old Empire displayed such consistent prodigality in the erection of its period markers as did Calakmul. Occasionally, at other cities, two monuments or even more were erected on the same period-ending, but at Calakmul it is safe to say that practically every *lahuntun* and *katun*-ending between 9.9.10.0.0 and 9.19.10.0.0 was commemorated by the erection of more than one monument.

While the sequence of the *hotun,* or 5-year period markers, is by no means as complete at Calakmul as it is either at Piedras Negras or at Quirigua, the number of stelae found at Calakmul (because several rather than one were regularly erected at the *lahuntun* and *katun* endings) is actually nearly two and a half times as large as the number of stelae found at Piedras Negras and nearly nine times as large as the number found at Quirigua. Provincial as the city seems to have been, judging from the art of its sculptured monuments, when it came to mass production, Calakmul may fairly be said to have surpassed every other city of the Maya civilization now known.

The Initial Series of Stela 43 surely reads 9.4.0.0.0, more than a century earlier than the next earliest date, 9.9.10.0.0, recorded on two different monuments—Stelae 28 and 29. However, the stylistic characteristics of Stela 43 are such as to indicate strongly that it had been executed at a much later date than 9.4.0.0.0, possibly as much as two centuries later. Further, the other dated monuments associated with Structure B, in front of which Stela 43 is located, all date from 9.13.10.0.0 (Stelae 38, 40 and 41), nearly two centuries later than 9.4.0.0.0. Finally, there are a number of Calendar Round dates in the inscription on Stela 43, which, although apparently without connecting

Secondary Series numbers, may be much later than 9.4.0.0.0—perhaps as late as 9.13.10.0.0—any one of which may record the dedicatory date of this monument.

Mr. Bolles found that the two principal mounds, Structures A and B (see map of the city), are about the same height, approximately 150 feet. However, since Structure A is built on somewhat higher ground than Structure B, the latter is in reality the higher as well as very much the larger, covering an area 425 feet square, compared to an area, roughly 250 feet square, covered by Structure A. Structure B also, judging from the dates of the monuments associated with it, is 30 years older than Structure A, having been dedicated in 9.13.10.0.0, whereas the seven stelae associated with Structure A were clearly dedicated on the *katun*-ending, 9.15.0.0.0.

The only building sufficiently preserved to permit the reconstruction of its ground plan is Structure C, of which Mr. Ruppert made a close architectural study and measured ground plan (see accompanying plan). This building is composed of two wings at right angles to the main middle section and it had originally twelve chambers and probably a roof comb.[4]

As Bolles was scouting through the forest with his gang of bush cutters opening the main lines of sight for the base map, he discovered many new monuments not found by Lundell. In fact, most of the 41 new stelae reported by the Calakmul expedition were found by Bolles in his exploration of the site incident to making the survey for the base map.

An interesting discovery was that of a large sculptured outcrop of limestone near the middle of a small plaza just west of the Ball Court. By chance, one of the lines of sight for the survey crossed this outcrop, which was completely covered with fallen leaves and humus soil save for a small section, perhaps three feet in diameter, lying directly in the line of clearing.

One of the workmen happened to notice that a human head of heroic size was carved in profile in deep relief—six inches—on the exposed upper face of

DATE GLYPHS ON STELA 89

A BEAUTIFULLY CARVED MONUMENT, FOUND ON THE SUMMIT OF STRUCTURE A, WHICH BEARS GLYPHS CORRESPONDING TO 471 A.D. OF OUR CHRONOLOGY.

[4] The roof-comb in Maya architecture, as its name implies, is a superstructure built on the roof of Maya buildings for decorative purposes.

STRUCTURE C, LOOKING NORTH

THIS IS THE ONLY STRUCTURE AT CALAKMUL SUFFICIENTLY PRESERVED TO PERMIT THE RECONSTRUCTION OF ITS GROUND PLAN. ORIGINALLY IT CONSISTED OF TWELVE CHAMBERS ARRANGED IN TWO WINGS AT RIGHT ANGLES TO THE MAIN MIDDLE SECTIONS (SEE GROUND PLAN).

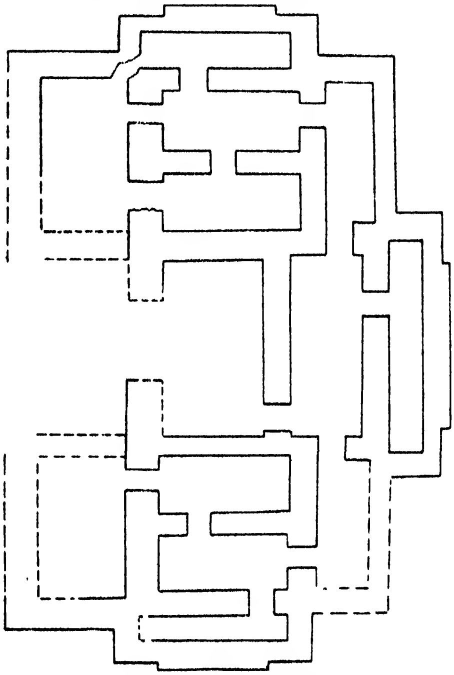
this rock (see illustration). When this outcrop was finally cleared it was found to be an irregular oval, the long axis measuring 21 feet, the short axis, 17 feet.

The entire top of the outcrop was sculptured with six or seven nude human figures, the tallest being nine feet in height; all these had their arms bound behind their backs, the cords showing clearly. There are several glyph-panels scattered over the outcrop but, due to the fact that these had been exposed to a maximum of weathering as well as to the fact that their relief was much lower than that of the captive figures, the interior details of the signs had entirely disappeared.

Other carving on outcrops of living rock in the Maya area of similar character are: the sculptured toad on a projecting ledge of the native andesite on the south side of the Copan Valley in Honduras;[5] the so-called Sacrificial Rock at Piedras Negras, Guatemala;[6] and the stalking jaguar, sculptured on a flat outcrop of limestone at Chichen Itzá, Yucatan, Mexico.[7] Mr. Stromsvik built a platform 17 feet above this sculptured rock at Calakmul, from which the design was photographed by flashlight at night.

Another find, possibly more significant scientifically, was Bolles' discovery of an ancient quarry a short distance north of the Main Plaza. Here two large blocks of stone, which, judging by their size and shape, probably had been intended for use as door lintels, are only partially quarried, one end and one narrow edge of each still remaining fast to the bed of limestone from which they were being worked. While by no means unique, definitely identified quarries at Maya sites are sufficiently rare to merit comment, and the one found this season at Calakmul is perhaps as good an example of this kind yet reported from any Old Empire site.

After turning the fallen monuments, Stromsvik devoted the remainder of his time to minor excavations, chiefly trenching in front of some of the standing stelae, in search of potsherds, of which a surprisingly large number were brought to light. In fact, five ten-gallon gasoline boxes of fragments were brought back to Chichen Itzá, probably the largest collection of potsherds ever obtained from any Old Empire site. In addition to this work, Stromsvik was able to collect parts (sometimes the entire piece) of at least 15 different *metates*.



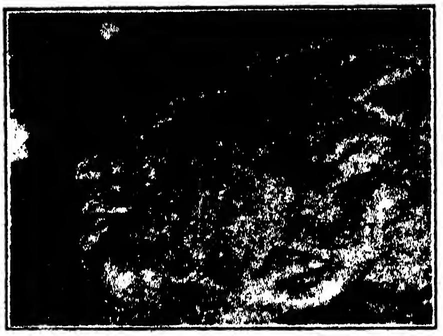
GROUND PLAN OF STRUCTURE C.

One of Ruppert's laborers reported having seen, two years before, a group of ruins some 15 to 18 miles by trail

5 "The Inscriptions at Copan," Carnegie Institution of Washington, Pub. No. 219, by Sylvanus G. Morley, pp. 377, 378.

6 "Researches in the Central Part of the Usumatsintla Valley," Memoirs Peabody Museum, Harvard University, Vol. II, No. 1, by Theobert Maler, p. 42, and plate VII, No. 1.

7 Carnegie Institution of Washington Year Book, 1923, p. 216.



SCULPTURED OUTCROP OF NATIVE LIMESTONE

SHOWING THE HEAD OF THE PRINCIPAL FIGURE. AN AREA 17 FEET BY 21 FEET IS COVERED WITH SEVEN CAPTIVE FIGURES REPRESENTED WITH ARMS BOUND BEHIND THEIR BACKS. THE LONGEST OF THESE MEASURES NINE FEET.

northeast of Central Buenfil near the former chicle camp of La Muneca. In addition to the usual mounds, pyramids and fallen structures, now overgrown by the forest, he stated that there were three carved stones like those at Calakmul, two standing and one fallen, with "letters" on them, "letters" being the general designation for hieroglyphics among *chicleros* throughout the Old Empire region. It was obvious that this informant was describing a site where there were at least three sculptured stone monuments.

Messrs. Ruppert and Bolles, having completed their work at Calakmul a day before the other members of the expedition were ready to leave, decided to pay a brief visit to the newly reported site near La Muneca. They left Calakmul on the morning of April 23, reaching Central Buenfil in time for an early lunch, then pushed on to the new site the same afternoon. In the dry season the nearest water to this site is four or five miles away and it was necessary for the party to make a dry camp.

That same afternoon Ruppert, while making a preliminary examination of the ruins, was stricken with his first attack of fever and obliged to take to his hammock. The next morning, with great courage and fortitude, although still suffering from fever, he dragged himself about the ruins until ten o'clock, when he collapsed.

In spite of the very limited time available and Ruppert's serious illness an incredible amount of work was accomplished. In place of the three sculptured monuments reported by the *chiclero*, 23 monuments were found. The site, Bolles reports, is located on two large terraced platforms on either side of a small ravine. He had time to make a sketch map of only the western platform where the 23 stelae are located. A hasty exploration of the eastern platform, however, failed to bring to light any other monuments, though such may nevertheless be there, he believes.

OUTCROP OF NATIVE LIMESTONE

TWENTY-ONE FEET LONG AND 15 FEET WIDE, ON WHICH APPEAR THE SCULPTURED FIGURES OF SIX PRISONERS. A PLATFORM WAS BUILT 17 FEET ABOVE THIS OUTCROP IN ORDER TO PHOTOGRAPH THE FIGURES.

Although neither member of the party is an epigrapher, they were both able to identify, in their very cursory examination of the monuments, at least four Initial Series, of which they deciphered the dates of three:

| | | | |
|---|---|---|---|
| Stela | 4 | 9.18. 0. 0. 0 | 530 A.D. |
| " | 3 | 9.19. 0. 0. 0 | 550 A.D. |
| " | 16 | 10. 2. 0. 0. 0 | 610 A.D. |
| " | 17 | ? | |

The first records the same *katun*-ending as Stela 80 at Calakmul, and the second the same *katun*-ending as Stelae 15, 16 and 64 at Calakmul. Stela 16 at the new site records the date 10.2.0.0.0. This date is (1) 60 years later than the latest date at Calakmul; (2) 10 years earlier than the only surely deciphered date at Chichen Itzá; (3) 20 years earlier than the latest dated monument in the Old Empire region; and (4) 40 years later than the latest dated object from the Old Empire region.[8]

[8] This is a tubular jade bead found by Dr. Thomas Gann on the Rio Hondo in British Honduras in 1931. It records the date 10.4.0.0.12 *Ahau* 340 as Period-Ending.

The discovery of this late date on Stela 16 is perhaps the most important single contribution from this new site. It is another link in the ever-strengthening cultural chain binding the northern half of the Yucatan Peninsula to the southern half and indicates that the Old Empire came to its close, or at least to the close of monument building activities, some time during the first quarter of *Baktun* 10. Messrs. Ruppert and Bolles rejoined the rest of the expedition at Central Buenfil on the evening of April 24.

Early next morning a start was made by truck for La Gloria. A broken steering knuckle delayed the expedition 24 hours. Finally, at four o'clock on the afternoon of April 27, the expedition left La Gloria on two tram-cars for the fifty-mile ride to Kanasayab on the Champoton River, the head of navigation for motor-boats during the dry season, reaching there at four o'clock the next morning, where a motor-boat was waiting to carry the expedition and its outfit

AN ANCIENT QUARRY ON THE NORTHERN OUTSKIRTS OF THE CITY

TWO BLOCKS OF STONE ARE HERE SHOWN IN COURSE OF BEING QUARRIED FROM AN OUTCROP OF THE NATIVE LIMESTONE OF THE REGION.

LA GLORIA, CAMPECHE

ON THE ROUTE TRAVERSED BY THE CALAKMUL EXPEDITION. AT THIS POINT CHANGE WAS MADE FROM PLATFORM CARS DRAWN BY MULES TO A FIVE-TON MOTOR TRUCK WHICH CARRIED THE PARTY THROUGH THE HEART OF THE RAIN FOREST TO WITHIN A FEW MILES OF CALAKMUL.

to Champoton at the mouth of the river of the same name.

Here the expedition changed to a small schooner with auxiliary engine and proceeded by sea to Campeche. The Institution party, again most hospitably entertained by Mr. and Mrs. Brydon, left Campeche for Merida the next day. Messrs. Ruppert, Bolles and Stromsvik returned to Chichen Itzá, April 30, the writer and Mrs. Morley the next day, May 1, having been absent from Chichen Itzá just four weeks to the day.

Perhaps the greatest scientific contribution of the Calakmul expedition is the discovery of such a large and definitely Old Empire city having such a wealth of sculptured monuments so far north as the southern part of the state of Campeche. Previous expeditions, also working from the north, had found in central Campeche sites more characteristic of the New Empire cities of the north than of the Old Empire cities of the south. The discovery of Calakmul, with a definite Old Empire flavor, both in its architecture as well as in its sculptured monuments, at the very heart of the Yucatan Peninsula, midway between the earlier cities of northern Guatemala (the Old Maya Empire) and the later cities of northern Yucatan (the New Maya Empire), fills a geographic blind spot in our picture of Maya civilization and satisfactorily bridges the gap between the two regions.

A number of other archeological sites described as having sculptured monuments, located in the same general region as Calakmul, not only in southern Campeche but also across the line in the northern part of the Department of Peten, Guatemala, hitherto unvisited by scientific expeditions, were reported to the writer and it is planned to send another expedition into this new archeological sub-province during the next field season (1933). Indeed, perhaps the most important immediate result of the Calakmul expedition may be said to be the opening up, the first general notice, so to speak, of this scientifically significant region, the no-man's-land between the Old and New Maya Empires.

# THE PARADOX IN NATURE AND MATHEMATICS

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I. WHAT do we mean by a paradox? In the broadest sense, I should call paradoxical anything which conflicts with "common sense." In a narrower sense, I consider a paradox in science a statement which apparently admits of a valid logical proof, but which, on the other hand, contradicts facts or conclusions which are established beyond a doubt. It sounds in itself a little paradoxical to distinguish between "common sense" and a logical proof, but I think we may agree that there seems sometimes to exist only a small correlation between the two.

According to these definitions, a paradox is something relative. What at one stage of the development of a science or of the individual mind may be a paradox will, once we clearly establish a fallacy in the reasoning or once we accept as in agreement with common sense something which heretofore had not been acceptable, become simply a sophism or a puzzle. As Rousseau said, "A paradox is a truth which has come into the world a century too soon." Then, once we see what is behind it, it ceases to be a paradox. A true paradox is a real challenge to the human mind and a standing menace to the very laws of logical thinking.

II. I shall first illustrate by some simple examples what I have just said, and then pass on to some paradoxa which have either been degraded to sophisms or puzzles only within the last generation or two or which still retain their proud standing of true paradoxa.

We may pass over the age-old proof that 1 equals 2. We inflict it on algebra freshmen to illustrate the nonpermissibility of division by zero.

On a slightly higher plane is the following "proof" that any two given angles are equal. (Fig. 1a, b, c.) Let in each of the three figures $\angle CAB = \alpha$ and $\angle ABD = \beta$ be the two given angles, which are assumed distinct. In each figure AC is chosen of arbitrary length, and BD is made equal to AC. Erect the two perpendicular bisectors on AB and CD, respectively. It is at once seen that from $\alpha \neq \beta$ follows that these are not parallel, and they must therefore intersect, say at G. Then, in each figure:

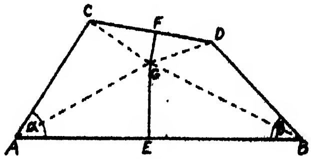



Fig. 1a

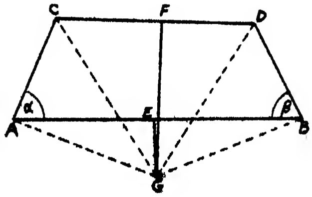



Fig. 1b

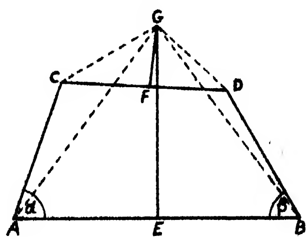



Fig. 1c

$\Delta AEG \cong \Delta BEG$; $AG = BG$;
$\Delta CFG \cong \Delta DFG$; $CG = DG$;
$\Delta ACG \cong \Delta BDG$.

Therefore $\angle BAG = \angle ABG$, $\angle CAG = \angle DBG$.

In 1a and 1c,
$\alpha = \angle BAG + \angle CAG$, $\beta = \angle ABG + \angle DBG$;
in 1b,
$\alpha = \angle CAG - \angle BAG$, $\beta = \angle DBG - \angle ABG$.

Thus, in every case, whether G lies inside the quadrilateral, or below AB, or above CD, we have $\alpha = \beta$, contrary to assumption. Apparently, all logical possibilities are accounted for; but a careful drawing will immediately reveal a neglected possibility.

Not quite so easy to see through is the following. (Fig. 2.) Consider a semi-cir-

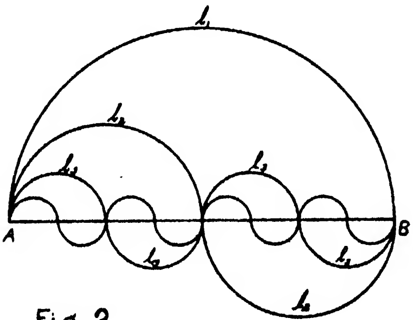


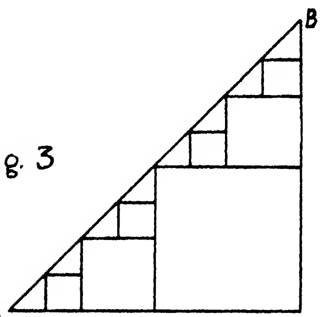

Fig. 2

cumference $l_1$ of a circle of diameter AB $= d$, so that $l_1 = \frac{\pi d}{2}$. As second step in our process, construct the two equal semicircular arcs $l_2$; as third step, the four equal arcs $l_3$; etc., etc. Clearly, the length of each wave line between A and B is equal to $\frac{\pi d}{2}$, that is, $l_1 = 2l_2 = 4l_3 = 8l_4 = \ldots = \frac{\pi d}{2}$. Now the argument is this: since at every step, however far we go, the length of the wave line is $\frac{\pi d}{2}$, it must also be $\frac{\pi d}{2}$ in the limit, when we repeat the process an infinite number of times. But then the wave line goes over into the diameter $AB = d$, and thus $\frac{\pi d}{2} = d$, $\pi = 2$.

True it is, of course, that, however small the diameters of the little circles be chosen, the length of the wave line is always $\frac{\pi d}{2}$. However, the argument holds only as long as we really are dealing with a wave line made up of semicircles. When we pass over to the limit, allowing the diameters of the small circles to reduce to zero, the resulting curve, the original diameter, is no longer of the same character as each of the wave lines $l_1$, $l_2 + l_2$, $l_3 + l_3 + l_3 + l_3$, etc. We shall have, it is true, $\lim_{n \doteq \infty} \Sigma l_n = \frac{\pi d}{2}$ but this only gives us information concerning what happens when the diameters *approach* 0, and says nothing concerning the diameters being *equal to* 0. In this case, there is a clear error in logical reasoning.

By the same kind of argument, one "proves" $\sqrt{2} = 2$, using the constructions indicated by Fig. 3, and compar-

Fig. 3




ing the zigzag lines along the diagonal AB with the diagonal itself.

An illustration of the same state of affairs, but more analytic in character, is the following: Consider the series $x(1-x) + x^2(1-x) + \ldots + x^n(1-x) + \ldots$. This is equal to $(1-x)(1+x+x^2+\ldots)\cdot x = (1-x)\cdot\frac{1}{1-x}\cdot x = x$, for $0 \leqq x < 1$. But for $x = 1$, one factor in each term of the original series is 0, and therefore each term is actually 0 (not: is approaching 0), and $0 + 0 + 0 + \ldots = 0$, even though we have an infinite number

of zeros. (To the mathematician, the world may have been created from an infinitesimal, but not from nothing, 0). So, for any x, $0 \leqq x < 1$, we have

$$\sum_{n=1}^{\infty} x^n (1-x) = x,$$

and also $\lim\limits_{x \doteq 1} \sum\limits_{n=1}^{\infty} x^n (1-x) = 1$,

but for $x = 1$,

$$\sum_{n=1}^{\infty} x^n (1-x) = 0$$

(not $= 1$). Graphically, the sum $s(x)$ of the series, as a function of x, is represented by a 45°-line from (0, 0) to (1, 1), but from which the point (1, 1) has been broken out and dropped to (1, 0) on the x-axis, leaving the diagonal without any last point at its upper end. (Fig. 4.)

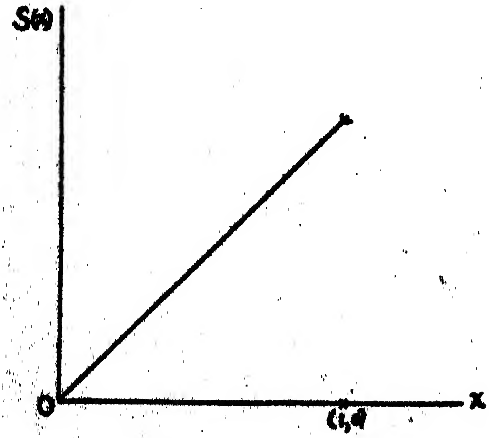



Fig 4

Another mathematical phenomenon of paradoxical appearance is the so-called "conditional" convergence of a series, according to which the sum of an infinite series may sometimes be changed by merely changing the order in which the terms are written down. For example, $1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \frac{1}{6} + \cdots = \log. 2$. But $(1 + \frac{1}{3}) - \frac{1}{2} + (\frac{1}{5} + \frac{1}{7}) - \frac{1}{4} + (\frac{1}{9} + \frac{1}{11}) - \frac{1}{6} + \ldots = 3/2 \log. 2$. Now this is very remarkable, because the first and second series contain exactly the same terms, since, obviously (1) every term of the second series is in the first series (being taken from it), and (2) every term of the first series is bound to occur sooner or later in the second series. The trouble in this case lies in the assumption that in a series of an infinite number of terms we are at liberty to change the order of summation just as we may in a sum of a finite number of terms. In other words, we are without justification assuming that the commutative law of addition, $(a + b = b + a)$, which does hold for a finite number of summands, will necessarily hold also for an infinite number of summands. Here, again, certain logical possibilities were overlooked.

III. From the ancient Greeks we have inherited a fair number of paradoxa. I do not know whether their explanation was usually known to the philosophers proposing them, but there can be no question concerning their influence on the development of Greek thought. Some of them are, even to-day, of considerable philosophical and metaphysical interest, since they deal with the same notions of infinity, limits, continuity, etc., which are at the bottom of most of our modern paradoxa in mathematics.

I mention first the mathematical paradox of Achilles and the tortoise: Assume Achilles to run ten times as fast as the tortoise; yet Achilles can never overtake the tortoise if it is given a start (of, say, 100 yards; but the actual distance is quite immaterial in the argument). In ordinary English, the argument is that before Achilles reaches a point which was passed over by the tortoise, the tortoise had time to move ahead; when Achilles reaches the new point, the tortoise has again moved on, etc. It is granted that Achilles comes closer and closer to the tortoise, but it is claimed that he never will be ahead of it. Without the mathematical conception of an infinite geometrical progression with a

finite sum, it really is impossible to satisfactorily explain the logical difficulties.

Xeno's paradox of the arrow claims that a flying arrow must really be standing still, because, before it reaches any given point A, it has first to reach the point B midway between A and its point of departure, O; before it reaches this point B, it has first to reach the point C midway between O and B; and so on. Finally, the arrow can never get started at all. The difficulty lies in vaguely formulated notions of continuity.

A purely logical Greek paradox is the one of the lawyer and his pupil. A famous lawyer agreed to instruct a candidate in law on the following terms: If the candidate won his first case in court, he was to pay a stipulated sum to his teacher; if he lost his first case, the teacher had no claim against him. After completion of the course, the student refused to pay and was sued by the lawyer. The argument is: This is the pupil's first case. The lawyer says, "You must pay me whether you win or lose the case; if you lose, because you are sentenced to pay by the court; if you win, by the terms of our agreement!" "Nay," says the student, "in no case do I pay; if I win, I do not pay, by the verdict of the court; if I lose, I do not pay, by the terms of our agreement." It is of course not admissible to use two standards of decision, as is here done.

A similar paradox, of the crocodile and the child, will be familiar to many readers.

Of considerably greater philosophical interest than these is the famous paradox of Epimenides the Cretan: Epimenides of Crete said: "All Cretans are liars." Now, Epimenides is himself a Cretan, therefore what he says is a lie. Therefore the Cretans are not liars. But Epimenides is himself a Cretan; therefore what he says is true; therefore the Cretans *are* liars. *Now,* E. i. h. a. C. . . . , in infinitum.—Obviously, in order to draw the first conclusion, one must have E. say: "Everything that any Cretan says, is a lie." The second conclusion then is, "Not everything that every Cretan says, is a lie," and from this, and the fact that E. is himself a Cretan, does not follow that what he said is a lie.

As a last paradox in this class, I mention a modern one, the so-called Richard's antinomy, which has led to serious controversies. We admit definitions of numbers, but each definition is to contain not more than one hundred letters, digits, mathematical symbols and punctuation signs; words are to be in the English language. For example, 22 (two symbols), twenty-two (ten symbols), $2 \times 11$ (four symbols) all express the same number 22. Obviously, there exist only a limited number of possible combinations containing not more than one hundred of these symbols, and, therefore, a limited number of different numbers which can be described by their use. Therefore, there must be a largest number which can be described or defined by not more than one hundred symbols. So far, so good! But now consider the number defined as follows: *The largest number which can be described by one hundred or fewer symbols, plus one.* We have used seventy-two (less than one hundred) of our symbols (including the hyphens), and have established a bad contradiction, by constructing a number larger than the largest one which could be constructed. The source of error in this paradox lies at the bottom of some of our most vexing modern mathematical paradoxa. The totality we are dealing with, while it seems to mean something definite, is not really well defined.

IV. To most of us the belief is nearly inescapable that there exists a harmony between the phenomena of nature, in

physics, chemistry and the other sciences, and the ability of the human mind to express the phenomena in what appeals to us as a natural manner, by the essential use of numbers, time and space. This belief is equally strongly ingrained in our minds, whether we believe in some marvelous dualism between the exterior world and the mechanism of our minds, or whether we consider the world, as it can be known to us, a creation of our minds, and the laws of nature nothing but an expression of the structure of our laws of thinking.

What do we encounter in reality? We very soon find in nature quite fundamental quantities, in terms of which many phenomena are described, and which one would expect to be of simple natural structure, whereas they are really of extreme complexity. Consider, for example, areas and circumferences of circles, and volumes and surfaces of spheres. These occur continually in the explanation of natural phenomena. But these mathematical concepts lead immediately to the number $\pi$, a number which has worried mathematicians for more than two milleniums. Let me say about $\pi$ that it is one of the very worst kind of numbers one can have to deal with, a so-called transcendental number. However far one goes in the decimal expansion of $\pi = 3.1415926\ldots$, nobody has ever discovered even the slightest trace of any law for the digits; $\pi$ has been computed to 707 places, but nobody in the world can at present from these 707 digits predict what the 708th digit will be. This is only one of its mildest forms of contrariness.

A similar situation, though mathematically of less complexity, confronted the ancient Greeks when they discovered that the diagonal of a square can not be represented as any fraction of the side, or, as we now say, that $\sqrt{2}$ is an "irrational" number. For centuries, this represented to the Greeks a true paradox; the question of "existence" of irrational numbers is very delicate, and the difficulties were not completely conquered before the latter part of the nineteenth century. The influence of this paradox on Greek thought and philosophy was very profound. It has been suggested that the very name *irrational* number bears traces of the difficulties encountered when such numbers were introduced.

Or, take yet another number, as important as $\pi$ for the quantitative description of phenomena, and every bit as unnatural in its behavior, the famous number $e = 2.71828\ldots$. Whenever in a physical or chemical formula we run across a logarithm, its base is originally not 10, or any other reasonable number, but instead, this number $e$, for which the logarithm has first to be transformed to a base 10 before we can conveniently make computations.

Again, consider the measurement of angles, which surely represent a basic concept in the sciences. Our degree unit is avowedly entirely unnatural and artificial. All formulae in physics and mathematics are simpler when we use natural or radian measurement. But then what? The simplest of all angles, one we deal with incessantly, is the right angle, and this is now equal to $\pi/2 = 1.57079\ldots$ radians. It is enough to make one begin to sympathize with the legislature of one of our states which, many years ago, all but passed a law, according to which $\pi = 22/7$.

Finally, one of the quite fundamental concepts in nature is rotation about a point in space. Yet, to handle this in a satisfactory manner, it is desirable to introduce so-called Hamilton's quaternions; and these are again quite unnatural to common sense, since they do not obey the so-called commutative law of multiplication, that is, if a and b are

two quaternions we do not necessarily have $a \cdot b = b \cdot a$.

Does it not seem paradoxical in the sense that it offends our common-sense feeling concerning things in nature, as they are and as they ought to be?

V. We carry this idea a little further. Just as we feel that there should be a perfect correspondence between actual phenomena and the mathematical formulae expressing them in terms of quantities which appeal to us as natural and simple, so do we also have the strongest conviction that there must be a uniform, consistent method of expressing all phenomena, in the sense that the foundations of any one branch of science must not logically contradict the foundations of any other branch. (This conviction is of course at the source of the so-called conflicts between science and religion). In the past, this was considered a consequence of the very laws of thinking: that if the fundaments of one branch of science contradicted those of another, they could not both be "true." Consistency was axiomatic, anything else was unthinkable. To-day, there is a strong tendency to take a more empirical view. Our phenomenological way of dealing with nature seems to be leading us to the possibility of a schism. At present, for example, the radiation theory seems to be based on an *emission* theory, while the greater part of optics is based on an *undulation* theory. Now these two contradict each other. In former times, this would have been (and actually was) considered an intolerable state of affairs. At present, physicists apparently still hope that a reconciliation will some time be effected; but there also seems to exist a frame of mind which contemplates at least the possibility of further development along these separate lines, without ever integrating the two into a common system. Offhand, it looks a good deal like saying that on Monday, Wednesday and Friday the sum of the angles of a triangle shall be 180°, but on Tuesday, Thursday and Saturday it shall be 179°. The disturbing feature of the situation is that this probably could be done. But surely, in the name of common sense, which tells us that if one is "true," the other is "false," we have a paradox of the most serious nature. So serious, indeed, that for many orthodox thinkers the foundations of all true science appear undermined. The new, and terribly complicated, theories of Schrödinger, Heisenberg, de Broglie may possibly bridge the gap between these two conflicting assumptions, but perhaps only at the expense of other assumptions of an equally paradoxical nature

In pure logic and in the foundations of mathematics, we are encountering the same kind of perplexing trouble, in the question of the validity of the law of the excluded third, in the form in which it is commonly applied in mathematics.

To give one more illustration, compare the static model of the molecule which the chemist creates, with the dynamic model of the physicist. In this case we do perhaps not have a true paradox; it is thinkable that the chemist works with the static model instead of the dynamic, because it is sufficiently complicated for his purposes, and the dynamic model would not give him any clearer insight into his problems. However, it is also possible that changing from the static to the dynamic model would be inconsistent with the deductions and conclusions of the chemist from his static model.

We see that it is hard to cling to our old cherished notion of a kind of preordained, pre-established harmony between nature, as reflected in its phenomena in physics, chemistry and the other natural sciences, on one hand, and our mind, expressing itself in terms of time, space and number, on the other hand.

VI. In a still broader sense, we encounter this paradox in an even more

fundamental aspect. There exists, and has existed since centuries, a large and influential school of scientific men to whom it is a dogma that all psychic actions and reactions are determined by the motions of atoms and molecules, and are uniquely decided by these motions. In other words, all psychic reactions obey, in a reflected manner, the law of cause and effect as we know it in physics. (However, it should be stated that this school is fighting with its back to the wall against certain theories which explain molecular motion in terms of probabilities of occurrences, in somewhat the same manner as a life-insurance company bases its business on purely statistical data.) When followed consistently, this mechanistic attitude leads to the doctrine of determinism, with a philosophy of fatalism hovering in the background. Here, at least, the human mind does not seem to be oppressed by the necessity of consistency, for, regardless of scientific convictions, nobody seems to act in life on the assumption that we do not possess freedom of action.

VII. Our next topic is again of considerable mathematical interest. When we draw a continuous curve, we shall ordinarily have at each of its points a definite tangent, that is, a definite direction. We may of course have on our curve a finite number of points for which there is no tangent, as at A, B, C in Fig. 5. But it is quite impossible for

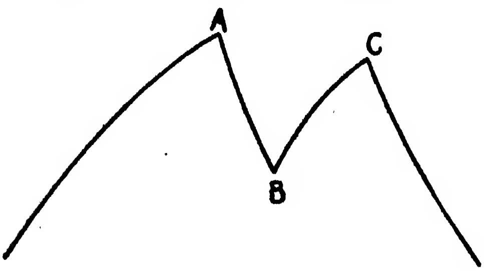



Fig. 5

us to conceive of a continuous curve which has at no point a tangent. The astounding thing is that such curves do exist; expressed in more technical terms, there exist functions, continuous in a given interval, and yet nowhere differentiable. A remarkably simple such function is indicated in Figs. 6a, b, c. The process here indi-

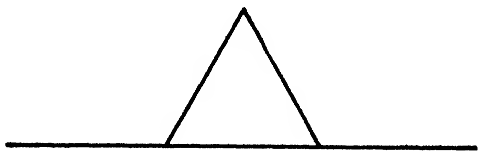


Fig. 6a

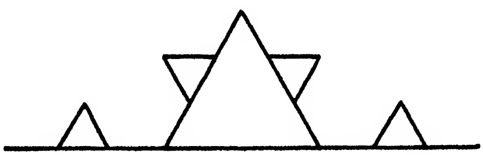


Fig 6b

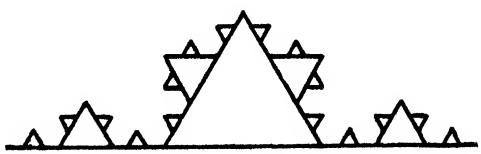


Fig. 6c

cated is in each step to take the middle third of each segment, and over it to erect an equilateral triangle. This process is continued indefinitely, and the curve to be considered is to consist of the totality of all vertices so obtained. One sees rather easily that, if one remembers the definition of a tangent as the limiting position of a secant when the two points on the curve approach each other, the secant will have a tendency to swing around violently as the points come closer together, instead of coming to rest. I only mention that

this curve has, as is very easily shown, the further remarkable property that the distance between any two of its points, measured along the curve, is infinite in length, however close the points seem to be.—The origin of the difficulty may be described as follows: from our knowledge of the curves which we are familiar with in ordinary mathematics, we deduce a property which we call "continuity of the curve." We then proceed to define this continuity in mathematical terms. Once this step has been taken, our hands are tied, and a curve is "continuous" when and only when it satisfies this technical definition. However, it may happen—as in this case—that our technical definition admits possibilities which we had not considered when the definition was set up.

Here we have a situation which looks like a true paradox until one goes very carefully and searchingly into the foundations of analysis. Such curves are often very expressively called crinkly curves.

It has even been suggested that possibly we deal in nature frequently with such crinkly curves. If we consider the barometric pressure as a function of the time, we get a zigzag curve like Fig. 7,

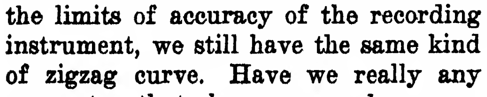


Fig. 7

and if we enlarge the curve, then, within the limits of accuracy of the recording instrument, we still have the same kind of zigzag curve. Have we really any guarantee that, however much we enlarge the scale, our curve will ever reduce to a decent smooth curve?

That phenomena in nature are at least continuous has been, up to recent times, axiomatically assumed. "*Natura non salta facit.*" But it is rather new to assume that she may possibly operate in such freak curves. Incidentally, it may be mentioned, as entirely in keeping with our modern revolutionary tendencies in the interpretation of sciences, that we are beginning to doubt the continuous nature of phenomena in general. The so-called "Quantum" theories in their newer forms invade not only the physical fields of matter and energy, but also our metaphysical notions of space and time.

VIII. Our last examples have undoubtedly carried us into the domain of true paradoxa. The outstanding example at the present time, as far as natural phenomena in their connection with space and time are concerned, is the theory of relativity. To allow space and time to lose their individuality, to merge them into one more comprehensive unit, represented by "world-points," contradicts so utterly our naïve common-sense conception of space and time that we can accept it at all only by looking on it as the final step in a direction marked by many previous evolutions. Of these I should consider two of outstanding importance for our purposes:

The assumption of a spherical earth rotating about its axis introduced a very tame type of relativity of position in the sense that "above" and "below" acquired different meanings for different observers, according to their position; and a very tame type of relativity of time in the sense that two different observers would, for example, not simultaneously have noon, according to their position on different meridians. Most of us will remember the amazement and incredulity with which we, as children, received the information that the Australians were walking on the bottom of the sphere without falling off, and that Europeans were eating lunch when we were getting out of bed.

The other important step was the introduction of non-Euclidean geometry, in the first half of the nineteenth cen-

tury. As is now well known, this settled a problem of twenty centuries' standing, concerning the foundations of geometry. One of Euclid's axioms, namely, the statement that in a plane there is, through a point outside a given line, always one and just one line which does never intersect the given line, however far one goes on either side, occupies a different position in the system from that of any of the other axioms. We may formulate the distinction in this way: The other axioms may be verified in any given case by a figure; but this axiom, the so-called parallel-axiom, can not be so verified, because the lines would have to be continued indefinitely for verification, and this is not really possible. As the final outcome of centuries of efforts it was discovered that perfectly good geometries could be built up by leaving all other axioms quite unchanged, but replacing the parallel-axiom by either one of the two following axioms: (a) there is *no* line through the point which does not intersect the given line; (b) there is always *more than one* line through the point which intersects the given line. These two new types of geometry are the Riemann geometry and the Bolyai-Lobatschefski geometry.

The fact that assumptions (a) and (b) seemed contrary to common sense or conflicting with preconceived notions of the character of "space" delayed the development of the theory for centuries. The assumptions themselves appeared paradoxical.

By their admission, we run into another serious difficulty: we now have three different "possible" types of space, the ordinary Euclidean space, the Riemann space and the Bolyai-Lobatschefski space. In what sense may we assert that these three types of space all logically exist, since apparently each one logically contradicts the others? It becomes necessary to consider them as three illustrations of a general geometry comprehending them all, just as, in our concept of a triangle, we have acute, obtuse and right triangles, although the three types are mutually exclusive when applied to any particular triangle.

This problem has been of quite outstanding importance in philosophy and metaphysics apart from mathematics, because it deals with the question of the actual character of the space we live in. It is not easy to understand the implications of the question: Is our space Euclidean, or is it non-Euclidean? It is apparently a question which has to be determined by observation. In the depths of our mind there are no hidden resources which can assist us in forming a decision. Already the immortal Gauss made astronomical and terrestrial measurements for this purpose, but without definite results. Certain it is that if our space is not Euclidean, it is "very nearly" so. Here, also, we have a certain relativity in our concept of space; it is no longer absolute.

In this way the human mind has been gradually prepared for the theories of relativity, but the prediction may be ventured that it will be a long time before the theory will be generally accepted as at all satisfactory to our common-sense notions of space and time.

IX. As a last, extremely important and interesting example of paradoxa I mention some properties of rational numbers, which are from a purely logical standpoint completely understood, but which will always seem paradoxical when judged by intuition. This whole group is only about half a century old, and has brought in its train a flock of perplexing questions which are not yet completely and satisfactorily disposed of.

We recall the familiar representation of real numbers by points on a straight line, once the two points representing 0 and 1 are arbitrarily chosen. We shall consider only rational points, $\pm m/n$,

including positive and negative integers ($n = 1$). We may even for our purposes restrict ourselves to the interval $0 \leqq x \leqq 1$. Between any two distinct rational numbers of this interval, $m_1/n_1$ and $m_2/n_2$, there is at least one more rational number, for example, $(m_1 + m_2)/(n_1 + n_2)$, ***and therefore an infinite number of rational numbers between any two rational numbers,*** however close together these two were chosen. But this is only a beginning!

If we assume a finite universe, then, however large it may be, it can contain only a finite number of electrons; therefore, in any interval, however small—for illustration, consider the interval of length .0000001 between .2385724 and .2385725—we have infinitely more rational numbers than there are electrons in any finite universe.

But the rational numbers only begin to exhaust the totality of numbers in an interval. Besides the rational numbers we have so-called *algebraic* irrational numbers, and these are vastly more numerous (in a certain sense) than the rational numbers. And after these algebraic numbers come the so-called *transcendental* numbers, to which $e$ and $\pi$ belong, and these are (in every sense) infinitely more numerous than the algebraic numbers. Quite interesting, but not very deep-lying, apparent paradoxa can be formed along these lines. For example, we may show that of two segments, one longer than the other,

(a) the longer contains more points than the shorter;
(b) the longer contains just as many points as the shorter;
(c) the shorter contains more points than the larger.

It will suffice to "prove" (c). Let AB be the longer, $A_1B_1$ the shorter, segment. Assume them arranged as in Fig. 8. Then: (1) To every point in AB corresponds a point in $A_1B_1$; (2) There are points in $A_1B_1$ to which no point in AB corresponds.—The explanation of the "paradox" lies in the fact—which is hereby demonstrated—that it is not logically permissible to speak of the "number of points" in a segment in the sense that we speak of, say, the number of apples in a barrel, or the number (finite) of electrons in a finite universe.

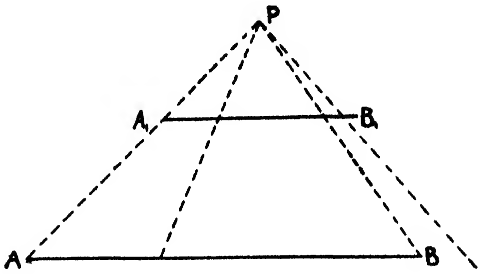


Fig. 8

More serious, because utterly irreconcilable with intuition, is the following paradox, the last one we shall mention.

We have seen that the rational numbers are so "dense" that in every interval, however small, we have an infinite number of them. How, then, is the following possible?

Consider all rational numbers in the interval 0 . . . 1, omitting, for simplicity, the points 0 and 1 themselves. Around each one of these, little segments can be placed, and the lengths of these segments can be so chosen that only an arbitrarily small fraction of the interval 0 . . . 1 is covered by any of the segments. To fix ideas, assume that each little segment is so placed over the corresponding number (that is, over the corresponding point) that the point is in the center of the segment; over the point 1/2 place a segment of length 1/100; over the point 1/3 place a segment of length $1/10^3$; over the point 2/3 place a segment of length $1/10^4$; over 1/4, $1/10^5$; over 3/4, $1/10^6$; etc. It is then true, although here not proved, that the sum of the lengths of all segments over all interior rational points

will be the sum of the geometrical progression $\frac{1}{10^2}+\frac{1}{10^3}+\ldots=\frac{1}{90}$. (It really is a consequence of the so-called "denumerability" of the rational numbers.) The fact that there is an enormous amount of overlapping of these segments acts in favor of the argument, as is easily seen.

X. I venture to hope that the foregoing treatment, brief and incomplete though it be, may help to bring out the following idea: In the development of science, we have always encountered the paradoxical. In the past, we have on the whole succeeded in gradually assimilating these paradoxa, sometimes quickly, sometimes after a struggle lasting over centuries. In some cases it has been necessary to revise fundamental concepts, such as our ideas of space. Up to quite recent times, we have succeeded in retaining intact our notions of logic, our ideas of cause and effect, and our conviction of an existing inherent harmony between the laws of the universe and the laws of the human mind. The work of the last generation has tended to shake our belief in the permanency and validity of these fundamental assumptions.

If our present-day paradoxa will also gradually permit assimilation within the old framework, science will have made tremendous steps in advance, but in the direction of the development of the past two thousand years. If the new paradoxa refuse to fit into our old framework, the human mind faces a situation more serious than anything it has ever before been exposed to—a situation which must mean either a retrogressive shallowness in our fundamental conceptions, or an intensification in understanding far beyond anything at present considered possible.

# GASOLINE AND LUBRICATING OIL

By Dr. GUSTAV EGLOFF

UNIVERSAL OIL PRODUCTS COMPANY, CHICAGO, ILL.

FORTY years ago there were just four automobiles in the United States. That was before the gasoline age, and kerosene was king of the oil industry. Gasoline was a waste product from the refining of crude oil during this period.

From 1859 to about 1905, gasoline, always present in crude oil, was a nuisance to the refiner. He was at his wit's end to get rid of it. He ran it into streams, rivers and lakes until the law called a halt due to the many resulting fires. The unscrupulous dealer adulterated his kerosene with the worthless stuff, resulting in many disastrous lamp explosions. In 1871, in New York City, the great chemist, Professor Charles F. Chandler, discovered that there were kerosenes being sold which were pure gasolines. Again the law intervened and drastic measures were taken to remedy this evil.

The advent of the motor car changed the picture. Motor cars burned gasoline, so gasoline became the chief product desired from crude oil. The number of automobiles and trucks increased more rapidly than the facilities for making gasoline. There are now 26,000,000 autos in the United States.

At the same time demand for kerosene was falling off. Oil lamps were being rapidly supplanted for lighting by manufactured gas and later by electricity. The oil refiner's position was completely reversed. His problem now was to increase his output of gasoline and decrease his output of kerosene. As some unscrupulous dealers earlier had mixed as much of their worthless gasoline with kerosene as possible, they now tried to get rid of their unwanted kerosene by mixing it with gasoline.

For a time it looked as though the oil industry would never be able to keep up with the mounting demand for gasoline. Prophets of gloom predicted a shortage of crude oil, fearing that the oil resources would last only a few years.

Such prophets failed to take into consideration the manifold applications of science to the oil industry. There never was a real shortage of oil and there is evidence present that there will be enough for at least a century. While the application of scientific methods has brought about the discovery of vast new pools of oil, science has made perhaps an even more important contribution to the oil industry and to the motorist in the field of gasoline production. The oil industry is producing at the yearly rate of 18,000,000,000 gallons.

Not only has the chemist shown the way to produce more than 300 per cent. increased yield of gasoline from crude oil in 20 years, but in addition he has produced a new and superior gasoline to that distilled from crude oil in the ordinary way. This was accomplished through the development of the cracking process.

Cracking produces gasoline of different chemical composition from that naturally present in crude oil. Instead of merely boiling off the gasoline fraction of petroleum, cracking subjects the oil to intense heat and pressure; temperatures of the order of 950° Fahrenheit and pressure of 400 pounds. The heat strives to force the oil molecules away from each other while pressure at the same time is forcing them closer together. In this Titanic struggle of forces the large hydrocarbon molecules from oils such as kerosene, gas oil, fuel

oil, or even crude oil, which will not operate a motor car, are shattered into small gasoline molecules which burn evenly in the engine and do their work quietly and without fuss.

A large part of the chemical research continuously going on in the oil industry is directed toward improving the anti-knock qualities of its gasoline. Anti-knock value to-day is expressed in "octane number." High octane gasolines mean smoother, quieter operating motors, with greater power output or more miles per gallon. They are a result of the modern cracking process. The gasoline present in crude oil, which nature has been forming through millions of years in the depths of the earth, is no longer suitable for the modern, high compression motor; hence it is being cracked into gasoline having the type hydrocarbons which will burn slowly in the engine. Nature's gasoline burns too rapidly and knocks violently during combustion in engines of most modern cars, which means harsh running and loss of mileage.

So we crack nature's oil—even gasoline—to make anti-knock motor fuel.

Motor-car manufacturers have been quick to take advantage of the constantly improved quality of gasoline to better the operation of their cars by increasing compression pressure. The higher the compression under which combustion takes place in the engine, without knocking, the greater the miles per gallon of gasoline. It is significant that nine years ago only four per cent. of all the cars manufactured had a pressure in the cylinders of 105 pounds or over, while in 1933 over ninety-three per cent. of the cars operate at this pressure. This increase or greater power output of motor-cars, could not have been accomplished without the development of the cracking process, which produces high anti-knock gasoline.

Hand in hand with progress in making anti-knock gasoline has gone development of means for preserving this value in gasoline and preventing the formation of troublesome gum. These ends have been accomplished by the discovery and perfection of inhibitors.

Inhibitors may be looked upon as chemical policemen which prevent air from reacting with the sensitive unsaturated hydrocarbons in gasoline. Thus they prevent any gum formation upon storage, or when the fuel is burning in a motor.

The development of inhibitors to prevent oxidation of gasoline made it possible to save millions of dollars a year which would be spent for chemicals to refine the gasoline to a marketable product. By the use of inhibitors, added in the merest traces, purification may be eliminated or modified, reducing loss of gasoline, preventing gum formation, and preserving anti-knock properties, as well as producing a better all-around motor fuel for the modern automotive engine.

The volatility of gasoline is another important property. "Volatility" in this sense is the ability of the gasoline to vaporize readily.

A gasoline which vaporizes readily is desirable for winter driving because it makes for quick starting. In summer, however, if the gasoline is too volatile it will even vaporize before it enters the manifold, causing gas bubbles which shut off the gasoline and stop the engine. This is known as vapor lock and frequently puzzles motorists who are not familiar with motor operation.

As a consequence oil companies regulate the volatility of their gasoline to a nicety so that it will perform properly whether the atmospheric temperature is thirty below or over a hundred. With better motor fuels and better cars, the motorist to-day gets twice as much value for his gasoline dollar as he ever got before.

Speed boats have traveled over 120

miles per hour, automobiles over 250, and airplanes over 400. Common cruising speeds for modern motor-cars are now about 65 miles per hour while ten years ago it averaged 35.

The motors which propel these vehicles must not alone be gasolined, but require careful lubrication. These mighty speeds throw a heavy burden upon the oil industry to provide lubricants which will keep the moving mechanisms apart.

The motor cylinders are fiery furnaces with temperatures of over 3,000 degrees Fahrenheit produced by the burning gasoline. Pistons in the cylinders move at 10,000 revolutions per minute. Under these conditions the lubricating oil must not materially change its viscosity or develop carbon to foul the cylinders. Moreover, it must have sufficient fluidity to permit the motor to start readily at arctic or desert temperatures.

More progress has been made in the manufacture of lubricating oils in the last few years than in the preceding thirty. Few people realize the vast difference in lubrication requirements between an engine driven at 65 miles an hour and one at 35. Up to 35 miles an hour, lubrication affords few problems. But at 65 the difficulties are greatly increased, and the punishment of lubricating oils is enormous when a motor drives a plane through the air at a speed of over 400 miles.

Another trend in motor-car design is toward lower body styles to facilitate higher speed and greater acceleration on the road. In order to maintain the necessary road and body clearances, smaller rear axles are required. Due to this trend toward smaller gears, higher engine torque, tooth pressures and rubbing velocities, a point is being approached where rear axles can not be lubricated with ordinary oils in a satisfactory manner.

Hypoid and worm gears, which are being adopted for the reason mentioned, operate under conditions of higher rubbing velocity than spiral bevel gears, and the use of these gears makes it necessary to provide special lubricants which will resist extreme-pressure operation. New extreme-pressure lubricants made up of blends of petroleum oils, saponifiable oils, and sulfur have been developed for such use.

To meet the modern lubrication demand careful selection of crude oils is essential. Crudes vary widely in quality, even when derived from different wells in the same oil field. Consequently, crude oils from particular wells in an oil field are specifically segregated for their lubricating oil quality alone.

Improvements in the process of refining have been made. The oils are distilled under vacuum and closely fractionated. Refrigeration temperatures of sixty below zero are being used to separate the wax from the oil. In some cases inhibitors are used to prevent the formation of crystalline wax in the lubricant. Solvent extraction, too, selectively removes from the oil those fractions having the best lubricating quality.

Synthetic lubricating oils have also been developed by hydrogenation and by the polymerization by aluminum chloride of oil produced by cracking. Not only have lubricating oils been developed to meet present motor-car requirements, but an immense amount of research is going on to anticipate the lubrication needs of the future. Millions of dollars are being spent by the oil industry in research to improve the quality of gasoline and lubricating oils, so as to anticipate the speeds of the future.

# THE RELATIVE NUTRITIVE VALUE OF LAND AND WATER PRODUCTS

By Dr. D. BREESE JONES

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ALL living things, in the last analysis, are dependent for their food supply upon the elemental constituents of the soil and of the air. Plants take the elements required for their nutrition, such as potassium, calcium, phosphorus, carbon, hydrogen and nitrogen, and manufacture them into sugars, starches, proteins, oils, mineral salts and vitamins. Animals can not manufacture these food compounds for their requirements, but are dependent for them upon the synthetic processes of plant life.

There is, therefore, a continual withdrawal from the soil of those elements which are essential for plant and animal nutrition. Under primitive conditions of life this material was returned to the soil with quite uniform distribution, so that the original fertility of the soil was largely maintained. Civilization in this respect has disturbed the balance of nature. The produce of the land is harvested, transported and, to a large extent, concentrated in certain areas, principally the large cities.

The soil is and always has been impoverished through another influence, namely, the leaching effect of rains, which carry away tremendous quantities of the elements of soil fertility. What becomes of all the material removed from the land by the two combined influences referred to? It finds its way ultimately into the sea, carried by streams and rivers, and through the agency of the sewage disposal plants of our cities. These elements of plant and animal nutrition, transferred from the soil to the sea, can be utilized by man and partly restored to the land only by farming the sea. This consideration lends special interest to a discussion of the relative biological value of land-farmed and marine-farmed products.

In animal nutrition food performs three functions, (1) it yields energy, (2) supplies material for the construction of body tissues, and (3) regulates many physiological processes. In order that a diet may satisfactorily perform these functions it must contain adequate amounts of protein, fat, carbohydrate, inorganic materials, and vitamins. Of course, water is essential and also a certain amount of indigestible material for roughage.

## PROTEIN

The chief function of protein in nutrition is to supply material for the construction of nitrogenous tissues, such as muscle, skin and hair. Protein also enters, to a greater or less extent, into the composition of practically every tissue in the body. Although fats and carbohydrates are the fuel material in food which supplies most of the heat and energy required by the body, proteins also contribute to the energy requirements of animals.

During the process of alimentary digestion proteins are converted into some twenty or more relatively simple compounds, which are called amino acids. These compounds may be regarded as the units or building stones of which proteins are composed. It is the amino acids and not the proteins which are assimilated. The proportions in which the amino acids occur in different proteins vary enormously. Some proteins are deficient or entirely lacking in one or more of them. It is because of

these differences that proteins vary so much both in their chemical and physical properties and also in their nutritive value. Gliadin, one of the chief proteins of wheat, is deficient in the amino acid lysine; zein of corn is almost entirely lacking in both lysine and tryptophane; gelatin is lacking in five of the amino acids. Wheat and corn, however, contain proteins other than gliadin and zein, which are better sources of amino acids. Consequently, in the whole grains these better proteins compensate in part for the deficiencies of gliadin and zein. Four of the different amino acids found in proteins have been proved to be essential for the normal growth and development of animals. They are lysine, cystine, histidine, and tryptophane. When the protein in the diet is lacking in any one of these four amino acids nutritional failure and death will eventually follow, no matter how much other food may be eaten.

In discussing the relative biological properties of the proteins of land and marine grown products, I shall first point out some general characteristics of the proteins of land products as a class.

The following materials constitute the most important land sources of food proteins: Meats and animal products, milk, cheese, eggs, cereals and seeds, nuts, vegetables and forage crops. Very striking differences in the nutritive value of proteins are found in some of these food materials. Analyses of the isolated and purified proteins of meat, milk, eggs and nuts have shown that these proteins are nutritionally complete, that is, they contain all the known essential amino acids in sufficient quantities to meet the normal nutritional requirements of animals.

The proteins of seeds, on the other hand, show striking differences in their nutritive quality. The chief proteins of most of the cereal grains are deficient or lacking in one or more essential amino acid. Wheat gliadin and rye gliadin are deficient in lysine, tryptophane, and histidine; zein, the chief protein of corn, contains no tryptophane nor lysine, and is deficient in histidine; hordein, the protein of barley, is low in all three of these amino acids, and oat gliadin is lacking in lysine and tryptophane.

In contrast to the seeds of cereal grains, those of the oil seeds and nuts which have been studied, including linseed, hempseed, peanuts, soy-beans, cottonseed, almonds, brazil nuts, and others, possess proteins of high biological value. They contain high percentages of the amino acids which are deficient or lacking in the cereal proteins.

Studies which we carried on a few years ago on the proteins of several kinds of beans disclosed an amino acid deficiency which is characteristic of the proteins of a certain class of legume seeds, including the common white navy bean, lima bean, adsuki bean, mung bean, velvet bean, cow-pea, and the lentil. The total proteins of these seeds are so deficient in cystine that young experimental laboratory animals will decline in weight and survive for only a short time when these seeds constitute the sole source of protein in their diet. That a deficiency of the amino acid cystine in these proteins was the cause of the nutritional failure was demonstrated by the fact that when a small quantity of cystine, amounting to only two or three tenths of one per cent. was added to the same ration, growth at a normal rate followed.

Compared with the proteins of other foods, those of vegetables and forage material have been only little studied. Such information as is available indicates that these proteins have a high biological value.

Fish, oysters, clams, crabs, lobsters, shrimp and scallops include most of the marine nitrogenous food products. The proteins of these foods have not been studied nearly so much as the proteins

of the land-farmed products. The amino acid content of the muscle tissue of several varieties of fish, of scallops, and shrimp has been determined. The biological value of the proteins of some of these products has also been determined by feeding tests with experimental animals. The proteins of all the marine foods which have been studied contain in satisfactory amounts all the nutritionally-essential amino acids. Osborne and Jones found that although there were differences in the percentages of some of the amino acids in the muscle tissue of different classes of animals, including fish, scallops, chicken and ox, the results "did not show such wide differences as are found between some of the different kinds of protein of vegetable origin." More recently, analyses of the muscle tissue of a representative crustacean, the shrimp, made in the Bureau of Chemistry, gave percentages of amino acids closely agreeing with those found for the other types referred to. Because of the difficulty of obtaining preparations of the proteins of oysters and clams suitable for amino acid determinations, no data are available showing their amino acid composition. However, the fact that young experimental animals grew to maturity at a satisfactory rate and were well nourished on a ration containing no protein other than that furnished by whole dried oysters and clams showed that the proteins of these mollusks are of satisfactory biological value. In general, it can be stated that marine animal life furnishes proteins quite similar, with respect to their biological value, to those of land-farmed animals and superior to the proteins of certain seeds, such as the cereal grains and beans of the genus *Phaseolus*. The extensive use of fish meal in stock and poultry feeds finds here additional justification, in that the amino acid composition of fish proteins is well suited to supplement the proteins of various grains.

### Carbohydrates and Fats

Many land-farmed food products are very rich in carbohydrates. From one half to three fourths of the weight of the dried matter of many cereals, seeds, tubers, roots, and fruits consists of starch or sugars. Fats are also present in large proportions in many animal and plant products of the land, such as nuts, cheese, soy-beans, olives, avocados, linseed, cottonseed, and peanuts.

Many nuts contain from 65 to 70 per cent. of oil.

Fish and shell-fish excel as sources of dietary factors necessary for the formation of body tissues and for the regulation of certain physiological processes rather than in their value as a source of fuel or energy.

Fish contain less fat, as a rule, than the higher animals. Shell-fish are not rich sources of fats and carbohydrates, although they are not lacking in these dietary factors. The edible portion of mollusks and crustaceans contains from 1 to 2 per cent. fat. Unlike most types of animal food they contain some carbohydrate, in the form of glycogen, or animal starch. This carbohydrate is said to be wholly digestible. It amounts to about 3 to 4 per cent. of the oyster, and about 5 per cent. of abalone.

### Mineral Elements

The excessive popular attention given to vitamins has somewhat obscured the general appreciation of the significance of the inorganic or mineral constituents of foods. The inorganic salts comprise a little over one fifth of the moist tissue weight of the body and are found, for the greater part, in the bones and skeletal structure. They are also present in all the tissues and fluids of the body and serve vital functions in many of the life processes. They maintain the delicate balance between the acid and alkaline reaction of the blood and other fluids; they take a part in the coagulation of the blood, in reproduction, in digestion,

and even govern to a degree the state of excitability and repose of an animal.

The most commonly known elements which regularly occur as constituents of animal tissues include calcium, phosphorus, potassium, sodium, iron, chlorine, sulfur, magnesium and iodine. In addition to these, traces of copper, zinc, boron, manganese, silicon and fluorine are usually found, some of which have been shown to be essential for the nutrition of plants and animals.

### Minerals

*Iron* has been long known to be an important constituent of blood corpuscles and is involved in the transportation of oxygen from the lungs to the cells of the various tissues in the body. About 15 milligrams of iron are required daily by an adult person. The nine land foods containing iron in the largest amounts are listed in the following decreasing order: Lima beans, peas, whole wheat, lean beef, spinach, oatmeal, raisins, eggs, and green vegetables.

Work done at the University of Wisconsin has demonstrated the importance of *copper* in the diet. Before the iron in the food can be assimilated there must be present minute traces of copper. A disease called nutritional anemia, characterized by a low supply of red corpuscles in the blood, can be produced in animals by feeding them a ration lacking in iron. Addition of suitable quantities of iron to such a ration produces no improvement in the condition of the animals, but when small quantities of copper are added along with the iron, rapid recovery follows. Of the land-farmed products the following 10 are reported to contain the most copper:

Copper Content of Some Land Food Products

(Quantity of copper expressed as milligrams per kilo of the fresh food)

| | |
|---|---|
| Wheat germ | 48.0 |
| Oats | 17.1 |
| Almonds | 13.0 |
| Kidney beans | 10.0 |
| Rye | 7.5 |
| Peas | 7.2 |
| Asparagus | 7.0 |
| Maize | 6.8 |
| Lentils | 6.6 |
| Barley | 6.5 |

The American dietary is probably more deficient in *calcium* than in any other one inorganic ingredient. Calcium is essential for bone and teeth formation, and it enters into the composition of many other tissues of the body. It plays a part in the process of blood coagulation. Children need more calcium than adults, requiring about 0.75 to 1 gram daily, an amount contained in one quart of milk. Land-grown foods rich in calcium are milk, cheese, carrots, cabbage, turnips, prunes, beets and oranges.

*Phosphorus* is also needed for bone structure and for the nuclear structure of the cells. Adults require about 1 to 1.5 grams daily. Good sources of phosphorus are milk, egg yolk, cheese, whole wheat, beans, oatmeal, lean beef, nuts, fruits and vegetables. A lack of either calcium or phosphorus may be followed by rickets, a disease common among children.

*Magnesium, sodium, potassium, chlorine* and *sulfur* are so widely distributed in foods that the question of their deficiency in the diet is generally of little concern. McCollum has recently demonstrated that a lack of magnesium in the diet of rats produces a dilation of the capillaries, tetany, and other symptoms of abnormal condition. He also found that manganese, a common constituent of foods, is essential for normal reproduction in animals.

*Iodine,* an essential constituent of the thyroid gland, is present in the body in a mere trace. It plays, however, a very important rôle in human health and life. Iodine in particular is one of the mineral elements in which the soil in certain areas is deficient. The relation between

deficiency of iodine in the diet and the incidence of goiter is well known. Certain cities in goitrous regions have introduced iodine into the drinking water supply.

As a class, most of the cereal grains, tubers, tropical seeds and nuts are deficient in calcium and sodium, and in some cases in iron and iodine. Increased incidence of disease in cows has been observed when they were fed rations deficient in calcium. It has been found that the growth, health and reproductive capacity of pigs fed rations consisting of cereal grains were improved when salt mixtures were added to the rations. A high mortality of sheep in a certain section of Michigan disappeared when mineral salts found in deposits near one of the Great Lakes were added to their diet. Animals grazed continuously on certain areas in New Zealand have been shown to suffer from malnutrition due to a deficiency of iron. The trouble was avoided by transferring the animals to pastures richer in iron. The symptoms were also relieved by giving them iron salts. In a certain section of Montana where the supply of iodine is low, an enormous loss of young pigs was shown to be caused by a deficiency of iodine in the food of the cows. Administration of small doses of potassium iodide prevented the high mortality.

Land crops depend chiefly for their inorganic constituents upon the soil. Unequal distribution of minerals in the soil is reflected in corresponding variations in the quantities of these elements found in the crops grown on those soils. In turn the animals are dependent upon the plant products and, to a lesser degree, on the water supply for the inorganic elements needed for their nutritional requirements.

Large bodies of water, particularly the sea, contain a much more uniform and constant supply of inorganic food. The ocean is a vast storehouse wherein has accumulated throughout countless ages a mixture of practically all the elements found in the earth's crust, as they have been leached from the soil and carried down by the rivers and streams. Marine-farmed products are, accordingly, an excellent source of inorganic elements. Seaweeds have been long used as a source of potassium and iodine. Schemes have been proposed for recovering gold from sea water.

Sea-food, particularly shell-fish, is known to contain, besides the mineral constituents which have been long recognized as biologically essential, such as calcium, phosphorus, iron, and sulfur, also those elements which more recently have been demonstrated to be integral constituents of living tissues.

Several investigators have shown that oysters contain copper in quantities ranging from 4 to 3,300 parts per million.

Remington and collaborators found that oysters contain copper in greater concentration than is found in any other plant or animal. By feeding experiments with rats they showed that oysters possess marked curative properties in nutritional anemia.

It is recorded that the ancients used seaweed for the relief or cure of goiter. Just in what way seaweed was beneficial was, of course, unknown, not only to them, but to hundreds of generations that followed them. To-day, we know that one type of goiter is a consequence of insufficient iodine in the diet, and that seaweed is one of the richest sources of this element. Tressler and Wells state, "Oysters, clams and lobsters contain more iodine than any other marine food" and that "they contain about 200 times as much iodine as milk, eggs or beefsteak, shrimp 100 times as much and crabs and most ocean fishes 50 times as much."

The presence of manganese in oysters has also been established.

Other mineral elements have been found in shell-fish, which can not yet be

included in the list of elements demonstrated to be beyond question nutritionally essential. It has been known for years that marine plants and animals contain heavy traces of arsenic. Chapman found arsenic in the following products, the quantities being expressed as $As_2O_3$ in parts per million of the wet substance: Oysters, 3 to 70; shrimp, 12 to 40; lobsters, 18 to 110; crabs, 36 to 70; flatfish, 3 to 10. Fresh-water fish, including pike, perch, roach, snails and crayfish, were all found to contain arsenic.

Oysters were also found to contain zinc in quantities ranging from 70 to 2,100 parts per million and lead in quantities varying from 10 to 400 parts per million of the dry edible substance.

Whatever mineral elements may be added in the future to the list of those already accepted as essential for the normal nutrition of animals, we are justified in expecting them to be present in the crops of the sea.

### VITAMINS

Vitamins are doubtless the most popularly known of the different food factors. We read about them in books, magazines, newspapers, advertisements and labels on packages; we hear about them on the street, over the radio, and from the platform. Vitamins have been recognized as definite food components for only about 20 years. Animals can not grow, be healthy or live long without vitamins. Mere traces of them only are required. At present six different vitamins are generally recognized. They are known as vitamins A, B, C, D, E and G.

Without *vitamin A* young animals can not grow. Their vitality becomes lowered and they are less able to resist infections and disease, particularly those of the respiratory tract. A characteristic disease of the eyes usually appears. Administration of vitamin A promptly cures this affliction. *Vitamin B* is called the antineuritic vitamin. Absence of it in the diet results in loss of appetite, arrest of growth, derangement of the nervous functions, and other disorders. A lack of *vitamin C* in the diet causes scurvy, and, for this reason, it is known as the antiscorbutic vitamin. Deficiencies in bone and tooth development are closely connected with vitamin C deficiency. Formerly scurvy was common among sailors, soldiers and others compelled to live on dried and preserved products without fresh fruits or vegetables.

*Vitamin D* is called the antirachitic vitamin. Rickets, a disease widely prevalent among children, is caused chiefly by improperly balanced proportions of calcium and phosphorus in the diet. The utilization of these elements is controlled largely by vitamin D. Sunlight or ultra-violet light is also effective in curing and preventing rickets, and is in effect a substitute for vitamin D. *Vitamin G* is usually associated with vitamin B. Deficiency of this vitamin in the diet results in retardation of growth, digestive and nervous disturbances, lowering of vitality, and ultimately in the appearance of skin lesions characteristic of the human disease, pellagra. Although the symptoms produced in animals by feeding them a diet lacking in this vitamin resemble those of human pellagra, it has not been definitely proved that they are identical. *Vitamin E,* known as the antisterility vitamin, is required for the normal reproduction of rats. There are no data, however, to show that it plays a rôle in human reproduction.

As a class, fresh vegetables, particularly the green leafy vegetables, are the best general source of vitamins. With few exceptions, they are an excellent source of vitamins A and C. Nearly all those tested contain vitamin B in goodly quantities. Some are known to contain vitamin E, green lettuce being an excellent source. Vitamin G is also present in beet greens, spinach, kale, onions, water cress and other vegetables. Veg-

etables, however, are a very poor source of vitamin D.

*Cereals* constitute probably the one most extensively used food item of the vegetable kingdom. They are, however, very limited as a general source of vitamins. As a class, whole cereals, seeds and nuts supply liberal quantities of vitamin B, this vitamin being located chiefly in the seed germ, or embryo. Wheat germ and rice polishings are among its best sources. Wheat germ is also one of the richest known sources of vitamin E. On the other hand, this class of foods is a poor source of vitamins A, C, and D. One noteworthy exception is yellow corn, which is a good source of vitamin A.

*Eggs* and *dairy products* occupy an important position as a source of vitamins. Egg yolk is an excellent source of vitamins A and D. It also contains vitamins G and E in liberal quantities, and is a fair source of vitamin B. The white of eggs, however, is a poor source of all the vitamins, excepting vitamin G. Butter is rich in vitamins A and D. It contains some E, but little or no B or C. Fresh, raw milk contains in addition a fair supply of vitamins B, G, and C.

*Fruits* rank as one of the best sources of vitamin C, notably oranges, lemons, grapefruit and strawberries. Bananas, pineapples, and prunes are fairly rich in A. Most fruits are also good sources of B, but are low in vitamin D content.

*Muscle meats* contain but little vitamins A, B, C, and D, but they are a fair source of G. The *internal organs* of animals, however, particularly the liver, heart and kidney, are good sources of vitamins A, B, G, and C, but they are low in vitamin D content.

*Vegetable oils,* such as olive oil, cottonseed oil, coconut oil, and peanut oil, may contain some vitamin A and vitamin E, but they are practically devoid of the other vitamins.

From this brief survey it is to be noted that vitamins A, B, and C are widely distributed in the land-farmed food products, but that most of them are deficient in vitamin D. Herein lies a differentiation between them and marine-farmed products.

Cod-liver oil is the best known and most widely used natural product as a source of vitamin D. In 1929 nearly 263,000 gallons of crude cod-liver oil were produced in the United States. This represents only about one tenth of the cod-liver oil used for animal feeding, 90 per cent. being imported. Cod-liver oil is also one of the richest sources of vitamin A. It has been shown by several investigators that the liver oils of fish other than the cod, namely, the shark, skate, ling, plaice, coal-fish and haddock, are rich in vitamin A.

Fish oils are obtained from fish and from fish offal, a by-product of the fishery industry. The material is heated and the oil expressed. The cake is used as fish meal for feeding. The total product in 1929 of fish oils, other than liver oils, was in excess of 12,000,000 gallons.

Interesting studies have recently been made in a series of studies on fish oils by Nelson, Manning and Tolle. This work was carried on cooperatively by the U. S. Bureau of Fisheries and the U. S. Bureau of Chemistry and Soils. Tests were made to determine the relative value of the oils obtained from tuna, sardine, menhaden, salmon, Alaska herring, and Maine herring, as sources of vitamin D. If an arbitrary value of 100 be assigned to cod-liver oil as an expression of its vitamin D potency, then the oils tested would have the following relative vitamin D values:

| | |
|---|---|
| Tuna | 125 |
| Sardine | 100 |
| Menhaden | 75 |
| Salmon | 50 |
| Alaska herring | 30 |
| Maine " | 15 |

Tests made later on menhaden oils, especially prepared under different conditions so as to avoid as far as possible any destruction of vitamin A, showed

that such oils were fully equal in vitamin D potency to medicinal cod-liver oil.

Burbot oil, prepared under commercial conditions, was shown to be from 3 to 4 times as rich in D, and from 4 to 10 times as rich in vitamin A as good grades of medicinal cod-liver oil.

The fish oils are used chiefly in making soap and as drying oils, and to some extent for sizing leather and tempering steel. Much fish waste is also discarded without attempting to recover the oil. These oils, cheap and excellent sources of vitamin D, are finding increasing use in stock and poultry feeding.

A little more than a year ago, tests for vitamin A and vitamin D potency were made on different samples of salmon oil. Three different preparations of oil were used, a commercial salmon oil, an oil from commercially canned salmon, and an oil prepared in the laboratory from salmon offal, a waste from the salmon canning industry. Oils from the offal of different species of salmon showed wide variation in their vitamin A potency. Oils showing a distinct reddish color, obtained from chinook and sockeye salmon, contained much more vitamin A than oil from chum, which was practically free from color. Some of the oils contained as much vitamin A as good grades of cod-liver oil and twice as much vitamin D.

Clinical studies on thirteen children with active rickets, recently conducted to test the value of salmon oil in the treatment of this disease, showed that salmon oil was more effective than the average medicinal cod-liver oil and compared favorably in its rapidity of action with viosterol.

Tolle and Nelson state, "Statistics show there are approximately 300,000,000 pounds of canned salmon produced annually in this country. This fish contains from 6 to 10 per cent. of oil. From the data obtained on the vitamin D content of the oil in canned salmon, it is quite apparent that there is more vitamin D in the canned salmon sold in this country than in the cod-liver oil used for both human and animal feeding."

Because of the meager information on the vitamin content of shell-fish, the Bureau of Chemistry and Soils undertook a study of the vitamins in oysters, clams and shrimp. Oysters constitute the most valuable fishery product of the United States. The annual yield in this country is about 30,000,000 bushels. Clams come next in the order of importance. Randoin, in France, had previously showed that oysters were effective in preventing scurvy in guinea-pigs. Working with fresh Chesapeake oysters, we found them to be a good source of vitamins A, B, and D, but rather deficient in vitamin E. First generation females reared only 14 per cent. of their young. Six second generation females produced only 2 litters, comprising 6 young, none of which were reared.

Two species of clams, commonly known as "hard-shell" clams or "quahaugs" and "soft-shell" or "sand" clams, were used in our studies. Although both oysters and clams were found to be good sources of vitamins A and D, one striking difference between them was observed. Unlike oysters, which compare favorably as a source of vitamin B with foods which are recognized as excellent sources of this vitamin, clams were found to be devoid of this vitamin. Tests conducted on samples of clams obtained from different places and at different seasons, and also on different species, gave invariably negative results. As a source of vitamin A, clams were found somewhat inferior to oysters. On the other hand, they have more pronounced antirachitic properties and are a better source of vitamin E.

Work done at the University of Wisconsin has showed that canned oysters, a product available in most markets throughout the year, contain vitamin D in appreciable quantity.

# LAW AS A SCIENCE

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It would seem socially desirable, from one point of view, to have a system of law so certain and rigid that it could be applied to any conceivable situation with mathematical precision and accuracy. Then the legal consequences of particular conduct could always be known in advance. This would seem desirable so that people in the usual and comparatively simple situations may know what to expect of others, how to conduct themselves toward others and how to manage their business affairs without getting into legal difficulties. In more complicated situations under such a system, if laymen should become nonplussed, lawyers would be able to advise them as to the proper course to pursue, and would be able to predict with accuracy the outcome of litigation.

Any person who comes upon my land without permission and cuts down my trees is liable to me in damages. That rule is fairly certain. It applies equally to all people. The rule is known and, therefore, most people do not do such things. If it is not known generally, lawyers can advise as to the consequences of such an act. One of the techniques of our legal system for assuring this certainty and uniformity in legal rule is that known as *stare decisis* or the requirement that courts follow precedent. This principle puts a certain compulsion upon a judge to decide a particular case in the same way that similar cases have been decided before. It is more likely to assure certainty and uniformity than is a rule of action which permits each judge to decide for himself what should be done in the particular case. Different courts, in different localities and at different times having different ideas as to justice would in all probability reach different results on the same set of facts. To the extent therefore that legal rules are certain, impartiality and uniformity are promoted.

Suppose after a long line of decisions holding that removing another's trees without permission is unlawful, a judge with communistic leanings, influenced by the unequal division of wealth and impressed with the dire need of the particular trespasser for fire-wood for his freezing family, should exonerate the trespasser, what happens to the certainty of the rule? Can one now predict that under the circumstances of a particular case the old rule will stand? If one change in circumstances will break down the rule, who can say when another will not? Will not those who desire the trees of another be encouraged to help themselves? Will not increased litigation result from the increased number of such offenses, and from the lack of sureness as to what the outcome will be? Will not socialistically minded judges, with the disintegration of the rule begun, be encouraged to break down the rule further, perhaps for less justification? At any rate is it not probable that all the advantages of having a certain invariable rule on this point will now be lost? Assuredly lawyers can not now safely advise one as to his rights in such matters. Litigation will be much more of a hazard.

Laymen are wont to complain of the law when lawyers are unable to advise them definitely as to their legal rights, and yet they are extremely impatient of the doctrine which requires the following of precedent. They say that each

case ought to be decided on its own merits, or that the judge ought not to let precedent force an unjust result. Yet what could be more destructive of certainty of a rule than the failure or refusal of a court to follow a rule previously established by a long line of decisions? It is too frequently not realized that to the extent that there is a departure from precedent there is a sacrifice of certainty.

Much can therefore be said for certainty of legal rule and as one might expect there is a school of thought which advocates certainty as the most essential element in a legal system. The advocates of this theory might be called rationalists, since they believe all legal phenomena can be rationalized or systematized. By some of this school it is even thought that there is something of the divine in the arrangement of the legal firmament, and therefore a particular decision can be said to be sound or unsound, depending upon its conformity or non-conformity to the divine plan. They think to the extent that there exist doubts, differences of opinion or inconsistencies they are due to the judges' inability to discover or apply the law. The rules are there as an omnipresence in the sky, wanting but an intelligence adequate to recognize and apply them. The judge has but to cast about for the correct rule, bring it down and fit it to the case at hand and justice springs forth, pure and undefiled. Most laymen follow this philosophy. They look upon law as consisting of a set of precise and definite rules sufficiently comprehensive to cover almost any conceivable situation that might arise, and think that all a lawyer need do when asked a question is to open a book and run his finger down the page until it falls upon the rule covering the situation at hand. By then reading the rule he is able to tell his client exactly what his rights are, or what would be the outcome if action were brought.

But alas, do we have, or is it possible or desirable to have a legal system so certain, so rigid? Is it not simply an illusion? If our legal system is certain, rigid, unbending, how is it to grow or adapt itself to changing conditions? Obviously, there must be a limit to its rigidity. Must not rules bend when by a newer conception of morality they work repeated injustice? Must they not yield to a changing economic and social order? When looked at from this point of view it seems obvious that a legal system should be elastic, that is, rules should not be held to be unerring implements to be rigorously and relentlessly applied in all cases regardless of consequences. New circumstances, changing social or economic conditions may require a new or modified rule. But elasticity of rule is inconsistent with certainty of rule. Advantages of certainty of legal rule can be demonstrated. Advantages of elasticity of legal rule can be shown. One makes for stability, the other for progress, but how can a rule be both rigid and elastic? Here is the great paradox of legal science. Most of the difficulties of the law, most differences of opinion about principles revolve about this paradox. To what extent should a rule be certain? To what extent should it be elastic? If a rule results in injustice in a particular case, should the rule always yield to the exigencies of the occasion and a decision based upon the merits rendered?

Of late the traditional conception of law as consisting of a body of fixed invariable rules has been losing ground. During the last half dozen years legal philosophy has been in a ferment. I think the cause is traceable directly to the revolution that has taken place in the physical and mathematical sciences. The development of non-Euclidean geometry, Einstein's theory of relativity, the research of Heisenberg and Schrödinger on the structure of the atom, Fitzgerald's theory of contraction, Comp-

ton's work with electrons, protons and photons, I understand have modified if not demolished orthodox conceptions and principles in physics and astronomy. I am not informed that the physics of Newton has become completely obsolete, but his law that every body continues in its state of rest, or of uniform motion in a straight line, can be readily seen to have lost much of its vitality when we are told that no body is at rest, and that there is no such thing as a straight line.

As bearing upon the significance of recent scientific developments, Professor A. S. Eddington says: "The frank realization that physical science is concerned with a world of shadows is one of the most significant of recent advances.[1] . . . The modern scientific theories have broken away from the common standpoint which identifies the real with the concrete. I think we might go so far as to say that time is more typical of physical reality than matter."[2] And Bertrand Russell says, "The main point for the philosopher in the modern theory is the disappearance of matter as a 'thing.' It has been replaced by emanations from a locality—the sort of influences that characterize haunted rooms in ghost stories. . . . All sorts of *events* happen in the physical world, but tables and chairs, the sun and moon and even our daily bread, have become pale abstractions, mere laws exhibited in the succession of *events* which radiate from certain regions."[3] "In a word 'matter' has become no more than a convenient shorthand for stating certain causal laws concerning events."[4]

The point we are interested in is that physical laws once thought to be universal or immutable have been found to be limited in scope, transitory in nature or based upon erroneous assumptions. If principles of the physical world are unstable and transitory things, how much more are principles of the social world, where we deal to a greater extent with human conduct, will, motive, instincts and emotions. Can there then be a science of law?

This tearing down of long-standing physical laws has made many doubt whether laws, physical or social, have any place at all in nature. Perhaps they are mere devices of the mind to make the world about us comprehensible. Perhaps but for the mind of man there would be no laws of nature. One is reminded of the old question—Is there sound if there is no ear to hear?

A group of legal scholars began to fall under the influence of such philosophers and scientists as Eddington, Russell, Dewey, Whitehead and others, and the idea occurred to them that if long-established principles of physics and astronomy have gone to pot, maybe some of the moss-backed legal principles were not as stable as supposed. As a result there came forth a new philosophy of law known as legal realism, which has all but relegated to the scrap heap the entire collection of legal rules found in the books. Although most of its sponsors are to be found among members of law school faculties, its most untempered exponent is Jerome Frank, a New York practising lawyer, whose book, "The Law and the Modern Mind," is only short of sensational. If the so-called immutable laws of physics proved vulnerable to the attacks of Einstein and the modern physicists, how much more vulnerable were the comparatively insecure principles of law to the attacks of the new realists! Under their inexorable logic, venerable rules toppled over like tenpins.

This new school of realism attacks the validity and utility of systematic arrangement of legal phenomena in the form of legal principles. They deny that

[1] "The Nature of the Physical World," p. xv, 1929.

[2] *Ibid.*, p. 275.

[3] "Philosophy," p. 106, 1927.

[4] *Ibid.*, p. 280.

such an arrangement appreciably aids in predicting legal decisions. In formulating their creed they draw not only upon the science of Einstein, the philosophy of Dewey, but also upon the modern psychologists. As I understand it there are two phases of their thesis:

*First,* they deny that objective facts which have to do with legal controversy can be definitely ascertained or set forth and therefore can not be the basis for the application of set rules, assuming there to be rules.

*Second,* that as to any group of facts which a judge or jury conceives to exist, there is no inevitably applicable rule of law. In other words, the judge has such a choice of so-called principles or formulae of words that he can first reach any result he desires and afterwards find an applicable formula. It is impossible, therefore, to predict a result in any particular case by consideration of the facts and by a study of so-called principles of law, because the facts are objectively unascertainable, and a rule of law can be found to suit any purpose or reach any result the judge desires. The decision is really determined, say the realists, by extra-legal factors, such as the judge's education, race, religion, economic status and bias, psychological inhibitions, or repressions, political considerations, etc., etc.

Suppose we now give a more careful consideration to these two angles of the realists' philosophy.

### (1) Impossibility of the Ascertainment of the Facts

Ascertainment of facts, whether physical or social, involves the phenomena observed (*i.e.,* the objective) and the observer (*i.e.,* the subjective). The first is the origin of a stimulus and the second conveys and mentally records it. The result depends as much upon one as upon the other. Modern scientists recognize the importance of keeping in mind these two elements in fact finding. One of the reasons for the inaccuracy of old principles of physics was that facts differ with different observers, as well as with different objective phenomena. The theory of relativity, I am informed, involves the view that things do not just happen, but that they happen as they are observed to happen.

Suppose an automobile accident or some other event has occurred which gives rise to a dispute between two or more persons. There are a half-dozen witnesses. A controversy develops as to fault and as to a basis of settlement. X, one of the participants, consults his lawyer, and states the facts as he conceives them. But is X's impression or understanding of the facts an accurate picture of what actually happened? The facts can be made known to the lawyer only after passing through the senses of X and other witnesses whom the lawyer might call, and the various impressions of these witnesses may be entirely different. Experiments have shown that rarely do two or more witnesses see things alike. They will observe things that did not happen, or fail to observe things that did happen.

The variation in the mental picture of the several witnesses may be due to such things as:

(1) Defect in sight or hearing.

(2) The emotional state of the witness, and this in turn may have been determined by what the witness had for breakfast, how late he was out the night before, or even the amount of secretion of the various glands of his body.

(3) The witness's private or subjective sense of value and his ethical and moral views. His mind will draw colored inferences from the facts in spite of himself.

(4) The witness's own race differing from the race of others involved. He may have a strong prejudice against the colored race or the Jewish race.

(5) The extent and character of his education (for example, if he is an engineer he would see things others would not see), social class, economic and political background, affection or animosity towards particular individuals or groups they represent (*e.g.*, plumbers, labor unions, auto mechanics).

(6) If the controversy involves domestic relations, or matters of sex, the witness's attitude may be colored by his own experience in such matters. His own past may have created abnormal reactions to women or blonde women or men with Van Dykes or Southerners, Italians, ministers, college professors, Democrats.

(7) Childhood inhibitions or conditions, *e.g.*, a certain nasal twang in speech or cough may recall painful or pleasant memories.

(8) His power of recollection may be feeble or may be influenced by others to whom he has talked after the event. A story grows with repetition.

(9) Desire to state what his lawyer wants may have its influence and some lawyers have a way of letting a client know what facts are most favorable to his case.

(10) A witness, too, is bound to make inferences, deductions, and fill in the gaps of his memory.

(11) Then there is sometimes the very potent influence of bribery or other inducements to dishonesty or perjury.

If by reason of all or some of these various influences the picture in the mind of the witness is warped, how much more is the picture in the lawyer's mind distorted when he does not even have the advantage of directly sensing the phenomena with his own eyes and ears but must accept a second-hand, inaccurate description of a picture already distorted in the minds of the witnesses. The result is a grosser distortion in the mind of the lawyer. Now upon the basis of this twisted picture the lawyer is asked to make a prediction of what a judge would say are the rights of the parties when it can not be known what sort of a warped impression the judge himself will have as a result of a trial.

But the lawyer hazards some sort of a guess as to the rights of the parties and a trial follows. Now the trial court will be confronted with more or less or different witnesses than those conferred with by the lawyer. There will be many conflicts and inconsistencies in the evidence. Their testimony will be influenced in various ways by the psychological and economic factors that have been related, and the net effect in the mind of the judge as to the facts is likely to be far different from that in the mind of the lawyer. Furthermore, who can predict the effect of the judge's likes or dislikes as to the lawyers or parties in the case, his economic bias, racial or religious prejudice or other leanings or antipathies. Some contend that his decision may even depend upon what he has eaten for breakfast; hence the term gastronomical jurisprudence, which has been given to this school of thought. Are not all the diverting factors that warp a witness's impressions of the facts likely also to warp the judge's? If the dispute is between capital and labor, who can say how much his opinion will be determined by his bias for or against labor? If the question relates to domestic issues, how much will his decision be controlled by his personal feeling about marriage and divorce, sex conduct, etc.? How much weight will such as the following factors have—that one of the parties is a Jew, is a Catholic, is a Republican, a communist, is wealthy, wears a diamond stud, was born on a farm, is uneducated? It must be remembered that every case involves the making of innumerable inferences and deductions first by the witness himself, then by the lawyer in the case, and then by the judge and jury. The factors

enumerated are especially influential in these inferences. The judge, although not a witness of the facts giving rise to the dispute, is a witness of what transpires in the court room. He is a witness of what the witnesses say and how they say it. All the limitations of a witness and many more limit the judge, because many wills, emotions, prejudices lie between him and the first-hand facts. If the case is tried by a jury, their biases, racial feelings, economic status, likes and dislikes, etc., all influence their compromise verdict and complicate the situation manifold.

As Jerome Frank has put it:

> The "facts," as we have seen, may be crucial when, as is often the case, a question of "fact" is injected into litigation involving a fee-simple. And those facts are, *inter alia*, a function of the attention of the judge. Certain kinds of witnesses may arouse his attention more than others. Or may arouse his antipathies or win his sympathy. The "facts," it must never be overlooked, are not objective. They are what the judge thinks they are. And what he thinks they are depends on what he hears and sees as the witnesses testify—which may not be—often is not—what another judge would hear and see. Assume ("fictionally") the most complete rigidity of the rules relating to commercial transactions; assume ("fictionally") that decisions are products of fixed rules applied to the facts. Still, since those "facts" are only what the judge thinks they are, the decision will vary with the judge's apprehension of the facts.[5]

Without at this time giving any consideration to the law at all (which according to this school of thought can be applied in such a way as to reach any result desired) is it not practically impossible for a lawyer with a distorted impression of the facts to predict what sort of a warped impression of the facts will be made upon a judge's mind by a group of witnesses with a great variety of distorted and inaccurate impressions? And if a judge's decision is hard to predict, how much more hazardous is the verdict of a jury of twelve men?

[5] "Are Judges Human?" *U. of Pa. L. Rev.* 80: 35, 1931.

But the gauntlet of the lawyer's guess has not yet been run. His prediction is not merely based upon what a trial court will do. After all, the appellate court is the ultimate arbiter and the body that lays down the law upon which predictions are based. What further transformation and distortion will the case go through before it reaches this ultimate tribunal? This court does not even see the witnesses or hear their voices. They examine only the printed page. How inadequately it speaks. How remote it seems from the real facts. More than ever, inferences must be drawn to fill out the picture. But these judges have other leanings, biases, prejudices. To what extent do these color the interpretation of the facts, not to mention the application of the law to the facts? Does the ultimate picture in the mind of this court even remotely resemble the true facts as they actually occurred? After all, can the lawyer's advice as to the rights of the parties be any more than a guess?

### (2) Difficulty of the Application of Principles of Law

If witness, lawyer, trial judge or jury, and appellate judge have different conceptions as to the facts in a case, how can there be any agreement as to applicable legal principle, assuming there to be such? Principle can have no existence apart from facts. It has meaning only if tied up with concrete phenomena. But if people have different mental pictures as to the external phenomena correspondingly will the meaning of a principle vary from person to person? But a principle is a principle only in so far as it is to some extent general and compelling as it is carried from one group of facts to another, and used by one person and then another, thereby creating uniformity in application. There can be no uniformity and therefore no principle where mental pictures differ as to the facts to which the principle is to apply.

For this reason principles, if they may be called such, overlap and conflict. They are not mutually exclusive. Where there is overlapping or where two conflicting principles seem equally applicable, what is to be the result? The supposed traditional method of a court's reasoning is that the judge first discovers a general principle which covers the case in hand. Then, using this as a major premise and the particular case as a minor premise, the decision is deduced. But that this is not really what a court does may be illustrated as follows: It is a principle of law that in the absence of fraud or coercion persons of full age and of sound mind are free to contract and manage their business in their own way. Another principle is that unfair competition is unlawful. Suppose X, a manufacturer, sells his commodities (say radios) to B and other retailers throughout the country and requires each of them to agree (*i.e.*, contract) not to handle the radios of Y, or any other of X's competitors. Y complains that X's conduct is harmful to Y's business. Now if a judge wants to reach one result he may state his syllogism in this way:

In the absence of fraud or coercion people of full age and of sound mind are free to contract and manage their own business in their own way.

This transaction was free of fraud and coercion and X and B were of full age and sound mind.

Therefore, X and B should be permitted to contract that B shall not use any of Y's radios, and their contract is valid.

Or if he wants to reach the other result he may say:

Unfair competition is unlawful. For X to require B to agree not to handle the commodities of Y is unfair competition as against Y.

Therefore, the contract between X and B is unlawful and invalid.

Each of these principles seems equally applicable to the facts. Why should one be used rather than the other? The question after all is what influences operate on the judge's mind in causing him to select one major premise rather than the other. Would it not be his economic beliefs on the advantages of competition as compared to communism, or some other economic system, or upon his belief as to governmental paternalism as compared with a doctrine of laissez-faire? Since the factors which would influence a judge to select one or the other principle as his major premise can not be told in advance, his decision can not be predicted. If principle, so called, can be selected, narrowed or broadened to suit the judge's desires or purposes, or if the statement of principle is simply a rationalization of a conclusion previously reached by intuition, or by "hunch" or by other extra-legal process, can principle be any basis for predicting a particular judicial result? It should be noted here that after the judge has reached his conclusion by some intuitive or "feeling" process, he proceeds to write an opinion wherein he makes it appear that his conclusion was deduced from legal principles. He frequently does not tell why he selected the particular major premise in his syllogism, which after all is the real key to his decision. The assigned reasons are not the real reasons. Should the assigned, but unreal postulates be regarded as of any value as principles for future decisions?

A further objection to deductive logic as a legal technique is, according to the newer thought, that it is impotent as a device of discovery. Nothing that was unknown before can be revealed by a syllogism. Herman Oliphant in his introduction to Rueff's "From the Physical to the Social Sciences" puts it thus: "If the major premise does not include the case to be decided, it is powerless to produce and determine a decision of it." But, on the other hand, if the major

premise "is taken to include the case to be decided, it assumes the very thing that is supposed to be up for decision."[6] In either case the principle or major premise solves nothing. The syllogism, therefore, is sterile as a judicial technique.

So even if facts could be definitely and certainly ascertained (which they can not be) inevitable and exclusive principle could not be applied so as to compel or force a predictable result. Law, therefore, can not be schematized or set forth by systematic arrangement of rules. To attempt it is simply to bring an illusion of certainty. Courts "feel," "sense" or by some process of intuition or imagination reach their conclusions. They then rationalize, classify and fit into their conception of the legal system that result. The point is that the rationalization does not produce the result, but the result produces the rationalization.

So much for the new realism. Is it to be accepted in whole or in part? Is it nearer the truth than the old rationalistic point of view, which, as has been shown, would make law a comparatively rigid system?

It is my belief that the realists have performed a genuine service in knocking the props from beneath what might be called "rule hero worship." There can be little doubt that lawyers as a class have had and still have too much blind faith in legal rules. If they can but realize that rules are simply arbitrary, artificial legal devices created by the imperfect mind of man in his attempt to comprehend legal facts, and do not constitute a universal, inevitable, perfect or infallible system to be inexorably applied, the legal atmosphere would be clarified and law would likely become a surer instrument of justice.

I have a feeling, however, that although what the realists say is true, they have erred in emphasis on one side, just as the older school erred in emphasis on the other side. Their error lies in not realizing or at any rate not pointing out the relative weight in the whole legal scheme of things, of the matters about which they talk. This overemphasis is no doubt pardonable during the pioneering period but becomes misleading in philosophic summations or appraisals.

It is believed that a more accurate and helpful view lies somewhere between the two extreme positions that have been stated. It is submitted that there is a large part of the law that is fairly definite and certain, and that it should be; that in that part, rules, imperfect as they are, do control, direct and inform lawyers and laymen as to how to conduct themselves; that by reason of the existence of rules many disputes are settled without the necessity of litigation. Legal rules serve as guides to business men, property owners and professional men in their relations with each other. And, perhaps by reason of rules, the great bulk of legal business of the country never gets into court. It is only the doubtful or border-line cases that cause fights. But even in the doubtful cases legal rules serve as sign posts; they point the way to solution by narrowing the issue involved and by bringing to bear upon the question the pertinent considerations. It can not be denied that there are many extra-legal influences in the decisional process, but it is believed that in this process previous legal pronouncement and schematic formulation also weigh heavily with most judges. In spite of the insistence of the realists, rules of one kind or another will and should continue to play a most important part in legal thought and action.

Are there not cases where the preservation of the integrity of a rule, despite a particular result which on its merits may seem unjust, is worth more than a presently just result purchased at the

[6] Rueff, "From the Physical to the Social Sciences," p. xix, 1929.

price of the integrity of the rule? Suppose the officers of the law involved in the Lindbergh baby case had agreed not to prosecute the kidnapers in order to assure the safe return of the baby—a desirable end in itself. Would not such conduct have made other babies less safe from kidnapers? Would it not have given to kidnapers generally such encouragement that they would have extended their kidnaping activities? Suppose a poor man negligently injures a rich man to the extent of $1,000. The rule of law is that the injured party may recover his damages from the negligent party. But in this particular case it is a greater hardship for the poor man to be compelled to pay the rich man $1,000 than it would be for the rich man to fail to get the $1,000. Yet is that sufficient reason for denying the application of the usual rule? Suppose A and B make a contract by which A is to pay B $1,000 six months from date for a lot. Before the six months elapse, A loses all his money in a bank failure, the mortgage on his house is foreclosed, and he is let out of his job. It is probably more of a hardship on A to require him to perform his contract than it would be on B to deprive him of the advantages of his bargain. Yet is the justification here sufficient to warrant breaking down the rule that a man should perform his contractual promises? If an offer to contract is sent by post, an acceptance by post is effectual when posted even though delayed or lost. Suppose a letter containing an acceptance of an offer to sell goods is delayed and the offerer, believing his offer to have been declined, sells the goods to another before he receives the acceptance, and upon receipt of the acceptance he immediately sends notice of his action to the offeree, who in the meantime has done nothing in reliance on his acceptance. The equities here weigh pretty heavily in favor of the offerer. But can not a strong case be made out for holding the offerer to his offer? It is socially convenient to know that a letter of acceptance of an offer by post is effectual when posted. Business men can conduct themselves in accordance with this view if they know it is settled. Lawyers can advise against litigation questioning its soundness. The rule will thus promote the settlement of controversies out of court. Despite the injustice in this particular case, it can still be said that when a letter of acceptance is mailed there is a great probability that it will arrive in due course. Only one letter in many thousands goes astray. Rules of law should be made to fit the probable situation, and they should not be weakened by being disregarded in the rare case when some one is inconvenienced. This line of argument seems reinforced by the further consideration that as to what is justice in a particular case is frequently hard to determine. It is frequently a matter upon which reasonable minds would differ. If what is just—what is a proper balancing of equities—is a matter to be left to the court, should it apply its own conception of justice, attempt to determine what is the general opinion of the community, or the opinion of a majority of the judges who have given consideration to similar problems before? If it adopts the latter, it comes very near simply following the rule dictated by precedent. If the judge chooses to part company with the rule, he would probably do so upon the basis of his own opinion as to the justice of the case. Is that result, or the one followed by many other judges most likely to be just? Suppose in the case under consideration a court were to decide for the offerer, would that be a good decision? It would make room for the view in the future that an acceptance is valid when posted even though delayed, if that seems the most equitable result, or unless the offerer has changed his

position. As a result other kinds of cases would be brought, raising the question as to whether the equities favor the offerer. But is the possibility of a different result in a few cases worth the increased litigation necessarily involved?

The idea of the desirability of the certainty of legal rules may be illustrated by the playing of a football game. Imagine such a game played without definite rules determined upon in advance. The players would not know where or how to line up, whether to kick the ball or in what direction to run. The referee would be at a loss as to how to decide disputes. Suppose a referee should decide that no penalty should be inflicted for off-side play when the play resulted in no advantage to the opposing team or when the offender was *provoked* to get off-side by the violent language of his opponent. Such a decision would introduce a great deal of uncertainty and confusion into the play. When was the opponent's language sufficient to provoke? Did the opponent use offensive language? Were not the words really spoken by another than the opponent, etc.? How many touchdowns have been recalled because a ball carrier's teammate was off-side on the play? And yet in many cases it was obvious that the being off-side did not in any way contribute to the making of the touchdown. Still who would argue for a change in the rule because of the unjust result in the particular case? Certainty, uniformity and facility in referees' decisions and the possibility of adjustment to the rule by all players argue for its retention.

Suppose courts did not decide cases by rule. One can imagine that the reformists would then be clamoring for rules so as to expedite the business of the courts. The first thing thought of by a newly organized committee or council which has a great many decisions to render is a body of rules by which it may classify its cases and reduce many of its decisions to rule-of-thumb procedure.

A formulation of a set of legal principles is simply a method of organizing the legal phenomena found in judicial decisions. This is not only desirable; it is indispensable. This is not to say that a particular formulation is sound or true, all others being unsound. No doubt other formulations could be contrived which would produce very similar results, though the differing systems may appear in certain respects conflicting and inconsistent. The test of soundness is simply convenience and utility. To the extent that a system works it is sound.

I have no doubt that an entomologist could classify all insects upon an entirely different basis from that now generally adopted. He could draw his line of cleavage between classes at a different place or in different directions, and such new classification could probably be made as helpful for studying and understanding the insect world as the one now in use. Surely an astronomer could classify the stars in the heavens according to some other plan than the one now used, but how chaotic the heavens would seem without any plan. It must not be overlooked that in both the physical and the social world things do not naturally arrange themselves in classes or in accordance with principle. Such arrangements are simply the devices of the mind which make the external world intelligible and comprehensible. The arrangements are tentative, transitory, imperfect and incomplete. They leave gaps and overlap. Yet if they help to clarify phenomena and make them rational they serve an indispensable purpose.

Any one who criticizes systematic arrangements, because of inconsistency and incompleteness, must necessarily construct another system in his own

mind, whether he outwardly admits it or not. And how long will his new creation remain invulnerable to attack? The self-satisfied air of the critic who pricks only the balloons of others is amusing until the critic's own balloon crumples and falls to earth. Then one is moved to pity. The objection raised here is not of the altogether commendable occupation of balloon bursting but of the satisfied air of the burster.

It is also well to remember that as to many questions presented to courts there can not be given a satisfactory or proved economic reason for deciding one way or the other. That is, the economic considerations may balance each other, economic opinion may be divided, or, what is more frequently true, economic data on the problem are not available and can never be made available. Certainty then becomes the controlling economic consideration and this can be attained only by adhering to the rule.

It seems to me that the extreme realistic position is vulnerable at certain points. To the cry of the realists that facts and not principles determine decisions and that deductive logic is sterile, Morris Cohen in his "Reason and Nature" asks, "What facts?" A mass of unclassified, unrelated facts reveals nothing, means nothing. They must be organized upon some hypothesis or theory. Deduction, says he, is a necessary tool in determining the relevancy of facts to the hypothesis or theory. Cohen would, therefore, object to the realists' attempt to relegate the syllogism to the scrap heap as a futile tool. Even Dewey recognizes the desirability of schematizing the law for the purpose of explanation and as a guide to conduct. He says, "There is a wide gap separating the reasonable proposition that judicial decisions should possess the maximum possible regularity in order to enable persons in planning their conduct to foresee the legal import of their acts, and the absurd, because impossible, proposition that every decision should flow with formal logical necessity from antecedently known premises."[7] . . . "It is most important that rules of law should form as coherent generalized logical systems as possible."[8]

As I have already stated, recent developments in physics and astronomy do not give much encouragement to legal philosophers in developing a system of law that will aid in predicting the legal consequences of a particular course of conduct. If laws dealing with physical things can not be formulated, how much more difficult is it to formulate a system of law dealing with human beings who have wills, emotions and instincts. But it should be noted that the revolution in physics has been wrought in the very large affairs of interstellar spaces and the very small affairs of the atom, which according to Eddington is as porous as the solar system and whose next quantum jump can not be predicted. Things lying between these extremes are least affected; *e.g.*, rules still enable us to predict results in such moderately sized things as our own solar system. On August 11, 1999, it is predicted that there will be a total eclipse of the sun visible at Cornwall, England. This event will involve the relative positions of but three bodies—the sun, moon and earth. I do not know, but would venture a guess that Lloyds would refuse to issue a policy of insurance against the happening of this event. It is possible but so extremely improbable that some kind of a solar cataclysm will prevent, advance or delay this solar affair that the mathematical chances of its coming off within seconds of the scheduled time are probably several thousands to one. Other safe predictions can be made as to what will happen on that day in August, 1999. The chances are almost so great

7 10 Corn. L. Q. 25, 1914.

8 *Ibid.*, p. 19.

as to amount to a certainty that the Mississippi River will not be dry, that 212 degrees F. will still be the boiling point of water under normal conditions, and that steam engines, electric lights and radios will still work. These accurate predictions are made possible by the so-called classical laws of the physical sciences. Perhaps, then, there is a range in the legal field within which prediction of results can be made with probabilities weighing most heavily in favor of its accuracy.

It is the wise judge who can divine where rigidity should end and elasticity begin. But no one has more clearly set forth the relative force of these two opposing magnets than Mr. Justice Cardozo, the most recent appointee to the United States Supreme Court. He says:

> The law has its formulas, and its methods of judging, appropriate to conservation, and its methods and formulas appropriate to change. If we figure stability and progress as opposite poles, then at one pole we have the maxim of *stare decisis* and the method of decision by the tool of a deductive logic; at the other we have the method which subordinates origins to ends. The one emphasizes considerations of uniformity and symmetry, and follows fundamental conceptions to ultimate conclusions. The other gives freer play to considerations of equity and justice, and the value to society of the interests affected.[9]

> There is in each of us a stream of tendency, whether you choose to call it philosophy or not, which gives coherence and direction to thought and action. Judges cannot escape that current any more than other mortals. All their lives, forces which they do not recognize and cannot name, have been tugging at them—inherited instincts, traditional beliefs, acquired convictions; and the resultant is an outlook on life, a conception of social needs, a sense in James's phrase of "the total push and pressure of the cosmos," which, when reasons are nicely balanced, must determine where choice shall fall. In this mental background every problem finds its setting.[10]

> My analysis of the judicial process comes then to this, and little more: logic, and history, and custom, and utility, and the accepted standards of right conduct, are the forces which singly or in combination shape the progress of the law. Which of these forces shall dominate in any case, must depend largely upon the comparative importance or value of the social interests that will be thereby promoted or impaired. One of the most fundamental social interests is that law shall be uniform and impartial. There must be nothing in its action that savors of prejudice or favor or even arbitrary whim or fitfulness. Therefore in the main there shall be adherence to precedent. . . . But symmetrical development may be bought at too high a price. Uniformity ceases to be a good when it becomes uniformity of oppression. The social interest served by symmetry or certainty must then be balanced against the social interest served by equity and fairness or other elements of social welfare. These may enjoin upon the judge the duty of drawing the line at another angle, of staking the path along new courses, of marking a new point of departure from which others who come after him will set out upon their journey. If you ask how he is to know when one interest outweighs another, I can only answer that he must get his knowledge just as the legislator gets it, from experience and study and reflection; in brief, from life itself.[11]

[9] "Paradoxes of Legal Science," p. 8, 1928.

[10] "The Nature of the Judicial Process," p. 12, 1921.

[11] *Ibid.*, p. 112.

# THE ORIGINS OF THE FOOD PLANTS OF PUERTO RICO

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PERHAPS no country having a large quota of food plant species has so few dubious factors in their historical perspective as does Puerto Rico. Any country, especially in the tropics, more or less separated from its neighbors, and abounding in economic flora, would be expected to present many puzzles to the investigator searching for the original habitat and the precise source of the individual plant autochthons and immigrants.

The Island, comprising some 3,450 square miles of mountainous surface, and situate about midway of the Antillean Chain, some 4 or 5 degrees below the tropic of Cancer, has at present something over 500 species of food plants—not counting, of course, the hundreds of horticultural varieties. Roughly speaking, the origins of these economics may be grouped under three nearly equally important epochs: the prehistoric—the period from, say, 500 A. D. (when, we presume, the first human inhabitant appeared) to 1500 A. D.; the Spanish Régime—from the latter date to 1898; and the American Occupancy period—from 1899 to date.

Of the half thousand botanical species in evidence, approximately 150 belong in the prehistoric group, about the same number arrived during Spanish occupancy, and the remainder have come in since—very largely during the first "introduction boom" period, from 1902 to 1910, and during the second, from 1923 to 1929. Much still remains to accomplish: at least 200 valuable food-producing plants are as yet unknown to Puerto Rico. Only two other countries, however, vie with this Island in the number of species, cultivated, semi-cultivated and wild, of real value to the consuming public—the Philippine Islands, with at least 300 native food plants; and India, with probably around 300 native and perhaps 200 introduced species. Other Antilles, notably, Cuba, Jamaica, Hispaniola and Trinidad, were about as well supplied in the prehistoric period as was Puerto Rico.

The major part of the prehistoric food-plant introductions came in, obviously, *via* the Lesser Antilles route—from Venezuela up through Trinidad, St. Vincent, Dominica and the Windward Group lying to the east of Puerto Rico. Just how far back this line of migration extended, we may never know. Setting the peak of agriological expansion in the pre-Inca regions—Tiahuanaco, Machu-Picchu, etc.—at around 1000 A. D., it seems probable that no marked movement of crop plants thence, toward the western and southern shores of the Caribbean Sea, could have affected any of the Antillean islands much before 600 A. D. and perhaps not before 1000 A. D. The varietal differentiation of the few major crops in evidence in the Greater Antilles in 1500 A. D. can better be accredited to the splendid agriology of northern South America than to *per se* expansion *in situ;* the yautías, however, are an exception. Fortunately, since the discovery of fossil maize in Peru, it is no longer obligatory to route the entrance of that crop into the Antilles from Yucatan. A pretty theory is that Cuba obtained some or all of her maize from that ad-

jacent peninsula to the leeward, while the other Arawak countries got theirs via the Venezuela-Trinidad route; however, the paucity of prehistoric maize types in the Antillean region indicates that the crop came into the picture rather late, and it seems certain that the crop accompanied cassava thither via the lands along the south side of the Caribbean.

One feature in Arawak agriology must not be lost sight of—those Amerinds were good agriculturists but not very good fighters or explorers. Whether the Caribs or the Arawaks, or some earlier type of Amerinds, are to be credited with introducing into the Antilles such crops as cassava, maize, peanut, pineapple and some of the legumes, opinions may well differ; granting that the piratical and cannibal Caribs did spread more food-plants about the Caribbean regions, it is, however, logical to suppose that they had no good intentions or purposes in that constructive work. They made frequent trips from island to island, starting originally, presumably, from the mainland coast opposite Trinidad; and in their large, unsinkable dugout canoes they carried both fresh and dried provisions: the "head" of an "ananás," carelessly tossed into the seaside scrub during a makeshift feast (on local Arawak flesh, very likely) might readily establish a stand of pineapples there.

The peaceable Arawak farmers seldom dared to till lands in proximity to the seacoast; however, there were a few valleys in Puerto Rico which happened to be protected by swamps or dense forest on the seaside: Yabucoa Valley, in the southeastern part of the Island, was an example. Protected on three sides by mountain ranges, well watered and drained, and shut off from approach from the sea by a mile-wide swamp at the eastern edge, this fertile, alluvial and hill-wash valley was for centuries the scene of perhaps the best agronomy in Boriquen; and the name is in evidence: the mattock-like hoe, called the "*bucoa*," was their principal tillage tool—and the prefix *ya* meant "the place of" or "where": wherefore, *Yabucoa* was the hoe-place—a field of some ten square miles in area, supporting several thousand Arawaks, and an ideal site for the development of a primitive crop industry.

We shall never know much about the details of Arawak agriology: the early Spanish records are exasperatingly meager. The salient points in that picture of prehistoric food-and-shelter problems are, nevertheless, very interesting.

Crops were raised and harvested every month of the year. There were two rainy and two dry seasons, 50 to 75 inches of rainfall, warm or hot weather always, with a light northeasterly or easterly breeze about ten months of the year; clothing, none; shelter, simple—pole *bohios* or huts, one for each family, with leaf or grass thatch. Playgrounds were large, and kept clean. The *bohios* were in small groups—probably no large villages.

The two great root-crops, yuca (probably made up of *ya* and *iuka* or *huka*) and yautía, were their *pièces de résistance*. They were meat-hungry. The few bean-like seeds supplied insufficient proteids. The hutia, a splendid member of the Rodentia, weighing some ten to fifteen pounds and resembling a plump marmot, was their favorite game. Turtles could often be caught on the beach. Manatees abounded in the river mouths and bayous. Fish they caught in cotton-cord and bark-fiber nets—when the seascape was clear. Oil they had from the corozo palm nuts, as well as from the blubber-blanketed manatees and the turtles.

The Boriquen Arawaks, up to the arrival of the Spaniards, had spent most of their inventive efforts on their main

crop, yuca; for some unknown phenological reason the cassavas are exceedingly seasonal: the stem-cuttings (the only propagational material in use) do not sprout well, except at the end of the winter rains, and, while they are not much affected by either rains or droughts during their growing season, they ripen well only during the autumn dry season. Hence the Arawaks in Puerto Rico were constrained to dry the ripe roots just before the winter rainy season, and this *kasabe* served as their chief food for the winter and spring months. In preparing this, their only specially treated raw product, they invented a peculiar sleeve or cylinder of coarse fiber in which the grated or ground wet fecula was pressed to extract the poisonous juice; by suspending this contraption from a hut pole and hanging a heavy weight on the bottom end of the extensible sack the watery juice gradually was squeezed out, to be boiled down into a black, piquant, odorous, highly wholesome concentrate, called *cassareep,* which was used as a sauce—and still is—as a preventer of autolysis, in the famous West Indian "pepper-pot" and in meat sauces of the Worcestershire type. By the way, this yuca squeezer was perhaps the Arawaks' greatest invention in the industrial line, as was the mysterious "stone-collar" in the line of the ceremonial mise en scène.

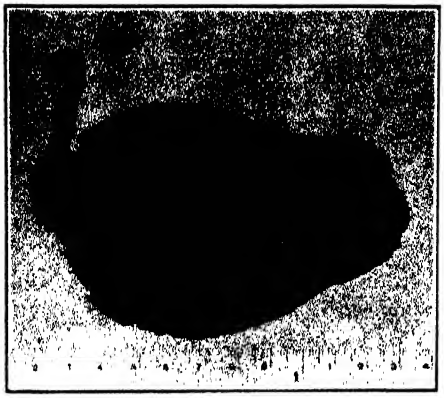
Probably nearly if not quite all the prehistoric varieties (probably 6, perhaps 10) of the yuca in the Boriquen were brought in from Venezuela, via the Lesser Antilles. The species very seldom sports, but very possibly seedling varieties did originate *in loco.* In the present day, some sorts set seed under favorable circumstances; probably, in Arawak days, however, with no open uncultivated ground, no yuca plant was ever left intact beyond its first year; theoretically, *Manihot Manihot* (L.) Coq. is a quasi-perennial—like its wild near relatives. (How often in printed —not written—accounts it appears as "Yucca"!)

The writer believes, with Dr. N. L. Britton, that there is no valid botanical distinction between the "Sweet" and the "Bitter" cassava varieties in any region. The Panamans claim that "any Bitter yuca turns Sweet when grown in Panama."

The second most important food plant of Boriquen was the yautía—taken as a class (like the yucas); and there is little doubt that it was quasi-endemic there. Although several somewhat bizarre varieties were in partial cultivation, at least, in northern South America, Mexico and the entire range of the Antilles, nowhere does the varietal list approach the size of Puerto Rico's.

Of the 39 species of *Xanthosoma* recognized by Engler and Krause, at least 8 and probably 10 are indigenous in Puerto Rico, and 5 of these were cultivated in Arawak times as root crops; undoubtedly several varieties, if not species, in evidence in 1500 A. D., have disappeared within the last four centuries. When the writer began the first yautía survey, in 1902, several of the 15 or more distinct cultural varieties in Puerto Rico were just on the point of extinction. While not quite conclusive, perhaps, the evidence of the complete seedlessness of the cultivated Puerto Rican yautías indicates many centuries of cultivation *in loco.* A remarkable homology is presented by the Oriental taros; like the yautías, they sometimes flower, but probably have never produced seed within historic times. The flowers of both groups are malacophilous —and snails are not very adaptable animals.

With two or three exceptions (in Jamaica, particularly) the Boriquen yautías are superior food plants, as compared with other tropical American varieties. Therefore, we can safely say

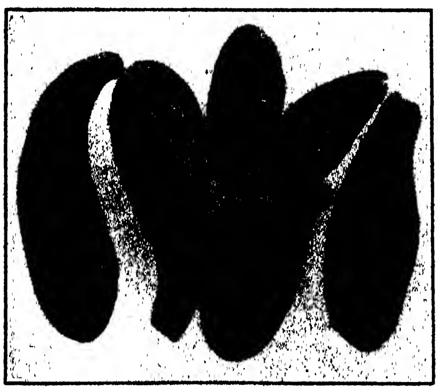


CHAYOTE (*SECHIUM EDULE*)
FRUIT, WITH SPROUT FROM THE SINGLE NON-REMOVABLE SEED.

that Puerto Rico is the home of one of the oldest cultivated root crops.

Two native Belembes (*X. hellebori-folium* and *X. brasiliense*) are used as spinach "greens" ("callalous").

Considerable uncertainty surrounds the status of the sweet potato (*Ipomœa Batatas*) in pre-Spanish Boriquen. It must have been brought thither from the old cradle of so many (60, odd) food plants, Central Western South America, via the Venezuela-Trinidad route; but it apparently was not in very good favor with the autochthons of Puerto Rico. Both the *Cumara,* or dry, and the *Apichu* (to use the old Inca names) or



YAMPEE (*DIOSCOREA TRÏFIDA*)
ONE OF THE WORLD'S BEST TABLE ROOTS.

moist types, were in evidence, probably far back in the Arawak régime. It is hard to account for the unpopularity of the batata among the farmers of those days; possibly it was a comparatively new arrival. Aside from the breeding of hybrid seedlings, there seems to be little change in the character of this old crop, in historical times.

The leren (*Calathea Allouia*) was very likely partially cultivated in the Island for a very long period before 1500. It never seeds. Its excessively long crop period—3 or 4 times that of the batata—must have militated against its general status as a crop. It was apparently of more importance in the Leeward Group —Dominica in particular—and seems to be a West Indian, rather than South American plant.

The two (white and purple) excellent Mapuey yams (*Dioscorea trifida*) were probably brought in before 1500 from South America. Presumably the few inferior indigenous yam species were of little importance in Arawak days; the good ones came with the slaves. Perhaps the "air potato," or gunda (*D. pilosiuscula*), was used as a hunger ration. Its negative feature is its bitterness (of the liver-shaped axillary bulbils), and the positive is its extreme durability. The ripe bulbils from old vines keep a year or more after picking. The dunguey (*D. altissima*) is the largest of the indigenous yams, and could always be found, when needs must, in the denser jungles; it often ascends to the top of the tallest trees and down again.

The teyote, or chayote (*Sechium edule*), appears to have originated as a food crop right in Puerto Rico. More varieties (6 or 8) are found here than anywhere else, and the vine seems happiest here. A 15- or 20-months-old plant may easily attain a length of 100 feet, and may produce a few hundred half-pound to pound fruits. The

starchy but always more or less fiber-filled, irregular-shaped root probably never was popular—and never will be.

There is much doubt about the old síncamas (*Cacara* [*Pachyrhizus*] *tuberosa*) being indigenous in Puerto Rico; the writer is inclined to believe that it arrived before the Spaniards, if not even before the Arawaks. It appears to be, outside of Mexico, an obsolescent root crop, due probably to its tendency to "run to vines" instead of bearing the large, sweet, turnip-like false tubers. We shall never know whether the Arawaks ate its large succulent green pods.

Another mysterious root-crop, which very probably arrived in the pre-Columbian era, is the arracacha (*Arracacia xanthorhiza*); either the Caribs or Arawaks undoubtedly brought it up from Venezuela—the only country where it has, strange to say, ever been popular (in civilized times). Since it apparently never flowers, we infer it has long been a cultigen. The name, of uncertain origin, is applied to several "tubers" of northern South America. Probably none other, of the dozen or more members of the Umbelliferæ which produce edible roots, is so prolific—potentially such a good root-crop; the large, irregular-shaped, odorous root, having the combined flavor of the carrot, celery, parsnip and squash, may be left *in situ* for years—portions being removed from the central "mother" clump as required. It is naturalized in Jamaica (if not indigenous).

Two more root-crops were probably cultivated, more or less, by the Arawaks: the Maranta (*Maranta arundinacea*), or arrowroot, known to the Spaniards as Yuquilla; and the Maraca (*Canna edulis*), or Tulucumá (from which the French devised "tous-les-mois"), or edible canna. Both these crops yield prodigiously under favorable conditions, and to the Amerinds their fibrous roots presented no great problem in starch extraction; and both would appear to be West Indian, rather than South American.

The Arawak fruit foods were fairly numerous. Fruits, however, with the exception of the mamey, were much less important in the dietary than roots.

The mamey (*Mammea americana*: the Latin built upon the Arawak name, rather than upon the shape of the fruit, presumably) was one of the commonest forest trees of Boriquen, and its very large, sweet, pulpy fruits formed, probably, a considerable part of the diet. Not only is the fruiting season very long, but the orange flesh dries readily and keeps well. It probably came nearest to being a really cultivated fruit in the pre-Spanish era.

ROSELLE (*HIBISCUS SABDARIFFA*)
THE PUERTO RICAN "RICO" IN A VARIETY TEST PLAT IN MANILA. (HEIGHT, 4 TO 7 FEET.)

The jobo (*Spondias Mombin*) was from the very beginning the most common wild fruit; unlike the mamey it is not particular as to soil or location.

These "hog-plum" drupes, pale yellow, an inch long, with a sweetish, slightly turpentiney taste, cover the ground in season under the 40- to 60-foot trees; the autochthons could, in crop time, always count on "filling up" with the mombins, though almost certainly even then the pulp was heavily infested with the (wholesome) maggots of the West Indian fruit-fly.

Around the coast there was always another wild fruit, a dry-pulp drupe larger than the mombin, and either black or whitish—the icaco (*Chrysobalanos Icaco*); the long crop season was a positive factor.

The pineapple (*Ananas Ananas*) was almost certainly a native of Brazil, and very probably the Caribs or Arawaks had purposely or otherwise brought it up to Boriquen some time before the sixteenth century, though it was hardly a food-plant until the Spanish began cultivating it. The autochthons here presumably had no name for it, wherefore the Spaniards applied the name piña—as poor a joke as coco, which the Portuguese gave to the big palm nut from the Orient, with its mouth-and-eye holes, reminding them of the children's "coco," or face mask. By the way, the Portuguese deserve some credit for still keeping the old Amerind name, ananás (accented on the ultima, as usual), for the low-grade, half-wild, tongue-torturing, sour lump of juicy fiber that has developed into one of the four best fruits within but four centuries. And by the same token, how shall we explain the fact that by the time the Americans arrived in Puerto Rico the Spaniards had somehow bred up or "selected" the giant "cabezona," one of the very largest varieties—and the only one ever exceeding 30 pounds in weight?

The jagua or genipap (*Genipa americana*) was probably never very popular, on account of its bad odor and strong taste; but it could "stay hunger" throughout Boriquen forest areas.

The jácana (*Lucuma multiflora*) and the ausubo (*Sideroxylon fœtidissimum*), fairly large forest trees, bore edible fruits, though the pulp was rather scanty. (The Spanish spelling of similar food-plant names is supposed to be based on the names applied by the "Indianos.")

The corozo palm (*Acrocomia aculeata*), known in other Antilles as grugru, was the only native palm in use by the Arawaks. Their stone axes were probably seldom used to remove the large "cabbage" or terminal bud—an excellent "salad vegetable," weighing some 10 or 15 pounds apiece; but both the ripe exocarp and the coconut-like endocarp were oily and wholesome.

The delicious níspero (*Sapota Achras* [formerly known as *Achras sapote*]) is supposed to be indigenous throughout the Antilles, but, outside of Central America and Panama, it appears to be a rare tree. A double handful of these russet-skinned fruits made a meal for any native lucky enough to find them: nearly 13 per cent. sugar, with but little waste.

Three or four kinds of murta (*Eugenia floribunda, E. axillaris,* etc.) grew here and there over the Island, and were consumed in season.

The cocobola (*Cocolobis uvifera*), which the Spaniards called "Uva de Mar," furnished considerable food in the coastal areas; its grape-like clusters of purplish berries are fair eating.

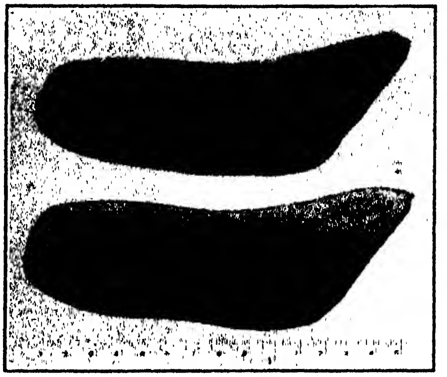
Another littoral tree or large shrub, the pajuil, cajuil or cashew (*Anacardium occidentale*) was probably common all around the Island in olden times; the false-fruit was a good thirst-quencher, if not highly nutritious; it is doubtful whether the Arawaks ever learned how to get the excellent kernel out of the corrosively poisonous shell. Possibly this food-plant was brought up by the Caribs from northern Brazil (or Venezuela), where it has always been known as acajú.

Very probably the cainito or star-apple (*Chrysophyllum Cainito*) was here before the Spaniards arrived—both the green and the purple forms of it; but in modern times it does not appear to be a forest species—as are the three species of caimitillo, of the same genus, with much smaller, but very edible wild fruits.

Opinions may differ, rightly, as to whether the guayaba (*Psidium Guajava*), or guava, is indigenous; the name seems to be Arawak, very significantly; if not strictly native, it might have been brought in either from the south (Brazil) or the west (Cuba and Central America). It was probably semi-cultivated by the Amerinds here—an excellent food species.

Of the far-flung Annonas, we can be sure of but one, the custard-apple (*A. reticulata*)—an important fruit in the more open regions. The Arawak name was probably cayur—also applied to the similar but hardly edible pond-apple (*A. glabra*); but the Spaniards called

PAPAYA (*CARICA PAPAYA*)
FEMALE PLANT (ABOUT 9 FEET HIGH AND 1 YEAR OLD).



PAPAYA (*CARICA PAPAYA*)
FRUIT OF THE VERY RARE SEEDLESS VARIETY.

it corazón—from its shape and size. Quite possibly the two superior sister species (*A. muricata* and *A. squamosa*), the guanábana or sour-sop, and the sweet-sop or hanon (Spanish anón) were indigenous (as the names would indicate).

Around the south coast there were three or four pitajayas, cactus fruits of the genera *Hylocereus*, *Leptocereus* and *Harrisia*: these large, or at least, attractive red or yellowish fruits, filled with a sweet, juicy pulp, may have been partially cultivated: what a wonder that the Spaniards kept the name!

The papaya or lechosa (*Carica papaya*) is of very uncertain origin; it was probably not used for food before the Spanish came. One or two native species of Passiflora, especially *P. maliformis*, the curuba, or, as the Puertorriqueños call it, parcha, were of food value to the "indígenas."

The guamá (*Inga laurina*) was probably used by the Arawaks as a forest food plant; the guaba (*I. vera*) may also have filled hungry stomachs in that time.

How mahíz, or maize, reached Boriquen is a problem. Since, with the finding of the famous fossil ear in Peru, we are confident that it originated somewhere south of Panama, and we have

either the Yucatan-Cuba or the Venezuela-Trinidad route—or both—to consider, the writer inclines to the former. Apparently little notice was given by the first Spanish settlers to the giant grass they called maíz (—the "h" being ever a precarious article in Spanish orthography!); but in Quisqueya (Haiti, of the Caribs)—the big island to the west, which he named "Hispaniola"—Columbus found immense fields of this magnificent cereal, the like of which has not been seen in this part of the world since: allowing for travelers' license, the fact remains that his small army had some difficulty in passing through the said vast cornfields of the north-central plain of Santo Domingo.

Whether the Arawaks had learned how to utilize the starch of three poisonous marungueys (*Zamia* spp.), is doubtful; the amount of food contained in the underground short thick stems of these indigenous "coonties" is nearly limitless—the small pockets in the coral limestone hills on both sides of the Island often carrying tons of the raw material per acre.

The bixa, or annatto, or achiote (as the present-day islanders call it), (*Bixa Orellana*) was undoubtedly here before 1500—but used more for body-painting than for food.

The Spaniards were, from the first, imbued with the idea of introducing a great variety of food crops into their newly discovered dominions in the new "India"; and they must be credited with establishing the world's first horticultural experiment station—near Toa Baja on the Plata River, not more than 15 miles west of San Juan, the then "Puerto Rico" of Boriquen (or, as they call it, "Borínquen").

One very questionable account indicates that Colón actually carried a few plants of sugar-cane from the Canary Islands to Hispaniola on his second voyage, in 1493: of course that could hardly have been possible, for it seems to have reached Las Canarias, from Madeira, not until 1503. The writer believes this "honey-bearing reed" arrived in Puerto Rico several years previous to 1520—when the aforementioned Royal Experiment Station on the North Coast was known to have quite a respectable collection of economic plants under propagation for distribution to the eager colonists.

The Spanish authorities, having no experience in plant introduction problems, but with laudable zeal, took over about everything they could lay hands on from the mother country; and when wheat, rye, olives, etc., protested against the tropical heat they blamed the colonists, but finally decided there might be something inimical in the climate, after all.

The four outstanding features of the Spaniards' early efforts at crop transplantation in the Antilles are, in order, sugar-cane, coffee, bananas and coconut.

The so-called "Arabian" coffee reached Boriquen from Hispaniola in 1736; the first Haitian plants were introduced from Martinique in 1735; Martinique had received a few plants, via France, from Java, about 1720. The African, or "Arabian" (*Coffea arabica*), was the only species *en evidence* in the Island, so far as we know, till the American Occupation: over two centuries in arriving, and even then it required another century to put the great industry on its feet.

A Spanish priest, Diego Lorenzo, took the coconut to Puerto Rico from the Cape Verde Islands a little before 1525; and quite likely he took one or more kinds of bananas thither at about the same time; another friar, Tomás de Berlanga, had found, in 1516, the Guanches of Las Canarias (the next archipelago to the north of Cabo Verde) reveling in their new crop, bananas, and no plant

SUGAR-CANE (*SACCHARUM OFFICINALE*)
CENTRAL STEMS (ABOUT 12 FEET) IN FLOWER.

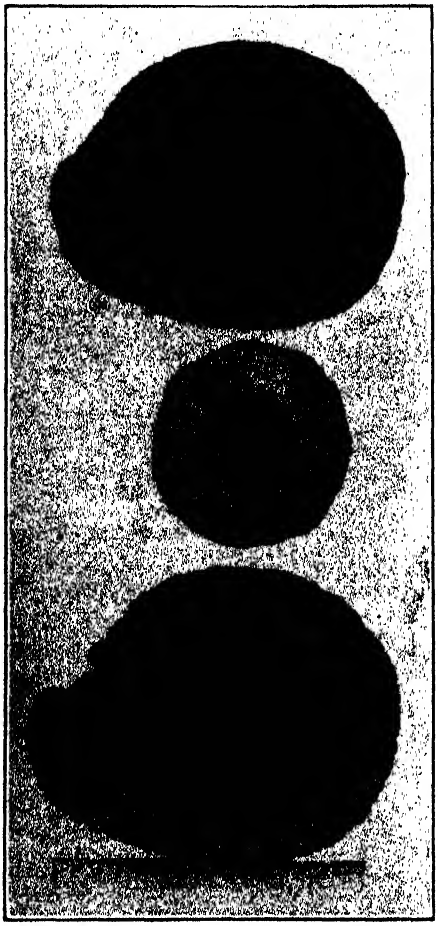
introducer would have neglected to transplant them into the West Indies at first opportunity; in fact, it appears that Berlanga did attempt to take the crop to Hispaniola at about that date. Notwithstanding rumors to the contrary, the writer believes no coconut and no banana, of any sort whatever, was known to any Amerind prior to 1516; what the "plátanos," reputed to be available for victualing ships, up a river on the mainland across from Trinidad, *were* is a great question. And here are other relevant questions: Why have the Puerto Ricans always called bananas "*guineos*" (guineas), instead of keeping their original African (Gulf of Guinea) name "banana" or "bamana"? Why did the Spaniards invent the name "plátano" for certain types of bananas—with not the slightest resemblance to, or connection with, the plátano, or plane-tree (sycamore)? By the way, it is possible that the Arawaks at times ate the coarse rhizomes of the bihai, or pómpano (*Bihai Bihai*)—the wild "ancestor" of the bananas.

Only the ubiquitous green and yellow varieties of coconut were introduced by the Spaniards, in our knowledge. What travelers these two old twin varieties have been for 400 years!—and where did they come from when they started out to cover the tropics, east and west?

The citrus fruits arrived early. Probably the sour orange and citron came first, and the "China," as the Puerto Ricans insist on calling the sweet orange, was distributed to Florida and the West Indian colonies about the middle of the sixteenth century. Another query: Why did the excellent sweet orange, brought around by the Portuguese at the beginning of the sixteenth century, lag behind, by *400 years* or so, the very inferior sour orange introduced by the Arabs, by the overland route, presumably, into the Mediterranean countries?

The lime and the sweet lime came

after the oranges and the citron. The rough lemon, formerly so popular in the Island, is, of course, an immigrant, if not a "sport" *in loco;* but we do not know *what* it is, much less *when* it came. The pomelo, as we should call the grapefruit (*C. paradisi*), is a West Indian upstart, but it probably originated



BREADFRUIT (*ARTOCARPUS INCISA*)
SEEDLESS FRUIT.

somewhere *near* Porto Rico about the end of the nineteenth century, or a little earlier; had any one supposed such a sour, bitter fruit would ever have become a $40,000,000 crop, its birthplace might have been located. Shaddocks (*C. maxima*) were fairly common in the Island on the arrival of the Americans.

The calamondin (*C. mitis*) from the Philippine Islands probably arrived some thirty years ago.

The mango did not reach Boriquen, it appears, till 1740; the good, named, India varieties began to appear here about 1905, when the U. S. Department of Agriculture took up the introduction work in earnest.

The panas, or breadfruits (*Artocarpus incisa* and *A. communis*), arrived in the West Indies from Polynesia in 1793, and probably reached Puerto Rico via Jamaica early in the nineteenth century.

Cacao was introduced from Continental America in 1636; presumably, only the common "Criollo" and "Forastero" sorts were known here before 1903 (when the writer brought in fourteen forms from Trinidad).

Although a wild avocado (*Persea portoricensis*) was discovered in the mountains of Puerto Rico (about 1925), it is certain that the Spanish introduced the common West Indian type, from the westward, probably rather tardily, during their régime. The Guatemalan and the named commercial varieties were brought in by the Americans, of course.

Of the miscellaneous fruits which were brought in during the Spanish régime, the following were of most importance:

The rose-apple, or pomarosa (*Eugenia Jambos*); early naturalized on the rainy side; the guinep, Spanish lime, or quenepa [perhaps an Amerind name] (*Melicocca bijuga*) may have been brought in before 1500, but seems never to be wild. The grosella (*Cicca disticha*) must have been brought around from the Orient long ago. The granadilla (*Passiflora quadrangularis*), from Central America, has long been widely cultivated—with good reason. The Oriental carambola (*Averrhoa Carambola*)

may have been brought in with the grosella, but is confined to one small district—under the deplorable name "piña." The "tropical almond," or almendro (*Terminalia catappa*) arrived at an uncertain period, probably from the Philippines. Mystery surrounds that excellent fruit, the marmalade plum (a stupid name for a 15- to 25-ounce fruit!), or mamey sapota (*Awiom zapota*, formerly known as *Lucuma mammosa* or *Calocarpum mammosum*); it was almost unknown before the American régime, yet quite possibly indigenous. The hevi, or jobo de la India (*Spondias dulcis*), and the common ciruela, or Spanish plum (*S. purpurea*); the rare jobillo, or ciruela amarilla (*S. cirouella*) is of uncertain origin. The old pomegranate (*Punica granatum*) came early, as, of course, did the olive and date—but they might as well have been left behind, with the peach, pear, apple and plum.

The Indian tamarind was, perhaps, a fellow immigrant with the mango; the very rare sweet variety probably never arrived.

Figs have never been able to long withstand the nematodes.

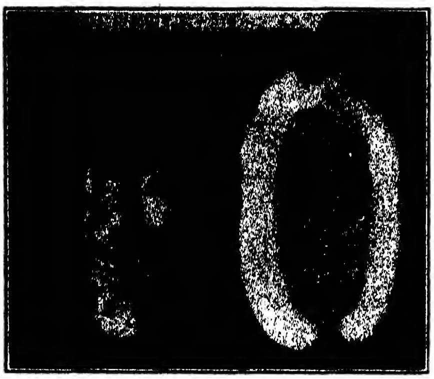
One of the most important introductions of the Spaniards was the Guinea yam (*Dioscorea rotundata*); it was the *pièce-de-résistance* on the slave ships. Some of the water yams (*D. alata*) may have come across in the same way. Hardly any class of important food plants are more shrouded in mystery as to their origins and early migrations than the yams: the 300 or 400 varieties scattered through the Far East, Middle East, Africa and Tropical America (and so painstakingly studied by Dr. Burkill, the quondam superintendent of the Singapore Botanical Gardens) present exasperating problems to the horticulturist, since many sorts are extremely localized, while many appear "cosmopolitan." The yellow yam (*D. cayen-*

GINGER (*ZINGIBER OFFICINALE*)

"HANDS" WITH "FINGERS" ATTACHED. STEM-BASE SCARS AT LEFT. "HANDS" LIE VERTICAL, 4 TO 6 IN THE HILL.

CACAO (*THEOBROMA CACAO*)

TREE 4 YEARS OLD, BEARING 65 FRUITS. EACH FRUIT (5 TO 7 INCHES LONG) CONTAINS ABOUT 30 "BEANS," WHICH, GROUND, ARE CHOCOLATE.



GRANADILLA (*PASSIFLORA QUADRANGULARIS*)

FRUIT, SHOWING EDIBLE SEED-SACS IN CENTRAL CAVITY.

*nensis*), the akam (*D. latifolia*), and the potato or papa (*D. esculenta*) are examples *ad hoc*.

The candle-nut, or nuez de la India (*Aleurites moluccana*), was brought in from the Orient or Polynesia long since. The chestnuts and the walnuts did not, of course, succeed; a native walnut (*Juglans jamaicensis*), however, is indigenous in the mountains of west-central Puerto Rico. The true Algarroba (*Ceratonia siliqua*) never has succeeded, but the native tree of the same name (*Hymenæa courbaril*) is a common open-country tree and was probably used by the autochthons for its malodorous but nutritious floury yellow fecula in the large hard-shelled pods.

Ginger, from India, was one of the most profitable crops of the Boriquen colonists in the sixteenth century—in fact, was so popular that a royal edict had to be issued restricting its cultivation (which was threatening the struggling sugar industry here then). Turmeric (*Curcuma longa*), also from the Orient, was here early in the Spanish régime, but probably never used much.

The Iberian vegetables were all tried out, and onions; several beans; okra (or gumbo—both African names, indicative of its origin; known now as guingambó) (*Abelmoschus esculentus*); beets (here called remolacha); carrots; peppers of sorts; lettuce; a few melons; tomatoes; eggplant (locally called berenjena); watercress (*Sisymbrium Nasturtium-aquaticum*), called berros; cabbage; cucumbers; several squashes; radish: all these have behaved as well as could be expected; two varieties of melon seem not to be found elsewhere at present; the hot peppers and okra flourish. Peas, turnips, watermelons, cauliflower, celery, garlic, chick-peas (so greatly relished by all Spaniards), the three kinds of Spanish salsify, spinach and most of the strictly temperate garden truck plants did not do well; yet the record for high-priced watermelons is held here, and spinach is sometimes cropped.

Whence and when the gandul, or pigeon-pea (*Cajan Cajan*), came, no one knows, but it has long been one of the Island's best crops; more "native" and named varieties are in evidence here than anywhere else, probably; the writer believes this valuable forage and food crop originated in the Congo Valley, and that it worked its way up through Egypt, where it became so popular, some 5,000 years ago, that it was put into sarcophagi: strange that only one country has really exploited it —Hawaii, where it probably had existed for years, unrecognized, before the seed for the great crop expansion arrived from Puerto Rico!

Rice has never been a popular crop in Boriquen. But several of the sorghum millets do very well if given a chance. The slave traders were probably accidentally responsible for bringing in Guinea grass (*Panicum maximum*)—as the "bedding" for the poor creatures below decks. That and malojillo (*P. barbinode*) were the two main forage crops in Spanish days; the latter came from South America.

One of the best small grains is

sesame, or ajonjolí; it was formerly quite popular among the "*jíbaros,*" or peasants.

The Spaniards liked well-seasoned dishes, and probably no other country is so well supplied with spice herbs—no less than 45 species being listed in "The Food Plants of Porto Rico."[1] The most interesting one, perhaps, is orégano chiquito (*Lippia helleri*), which was thought to be endemic, but the writer has seen it in markets in Santo Domingo; it "combines all the good qualities of all kitchen herbs." Spanish orégano (*Origanum vulgare*) and the queer, thick-leaved, powerfully aromatic orégano brujo (*Coleus amboinicus*) are excellent species, which should be in every warm garden. Basil, sweet marjoram and rue are fairly common, as are parsley and mint. But sage and caraway apparently awaited American occupation. On a par with the fetid valerian, so popular in olden times, is the culantro del monte (*Eryngium fœtidum*) which does flavor the stews of the *jíbaros.*

The strange, little-known curuba, pepino angolo or cassabanana (*Sicana odorifera*), probably from Brazil (not Angola), has long been seen in all the Island markets, though, like the güiro gourd (*Cucurbita lagenaria*), it is seldom seen growing; it would be of much interest to know where these old cultigens originated.

Vanilla, probably from Mexico, may have arrived before 1900, but was not a commercial crop until very recently.

The gherkin or pepinillo (*Cucumis Anguria*), may be indigenous.

The Himalayan raspberry (*Rubus rosafolius*), wrongly known in the Island as fresa (strawberry), has long been naturalized in the mountains, and is here one of the few fruits in the world which bear *continuously*: 10 or 15 cents buys a shoe-box full of the beautiful red-caps any day in the year! Some 25 other Rubi have been introduced since 1900, but few do well. The strawberry leads a precarious existence. The rampant (30 feet) zarza, or wild raspberry (*R. florulentus*) is a rare forest dweller.

Spanish grapes seldom bear well, even with careful attention. The parra or wild grape (*Vitis tiliæfolia,* vel *V. caribœa*) is of more value as a stock than food plant.

Whence and when came the malanga (*Caladium Colocasia*), one of the coarser, low-grade varieties of the strictly Oriental and Polynesian taro, we shall never know; it has, however, long been semi-cultivated—gathered from ditches and stream-banks—and is one of the cheapest foods of the jíbaros,

RICE (*ORYZA SATIVA*)
TEN "HEADS" FROM ONE SEED.

[1] "The Food Plants of Porto Rico," by O. W. Barrett; P. R. Department of Agriculture and Labor, 1925.

SESAME, OR AJONJOLÍ (*SESAMUM INDICUM*)

PLANTS (4 TO 6 FEET) IN FLOWER. THE SMALL WHITE, NEARLY HULL-LESS, SEEDS CONTAIN ABOUT 60 PER CENT. EDIBLE OIL.

or "country folk." There were no other taros here before 1900; but in Dominica there was discovered (*sic*) recently a strange taro, called "dasheen de azufre," which had been used by the "natives" of the interior of the Island for an unknown period of time; it seems to have been peculiar to that limited area and to have been cultivated by the "Indians." The occurrence of this cultigen (?) in Dominica, the malanga in Puerto Rico and the dasheen in Trinidad would seem to refute the idea that the taros ("*Colocasia*" spp.) are all paleotropical.

Tobacco (known to the Arawaks as cohiba), a masticatory and not a true food plant, was widely cultivated in the Antilles long before they were "discovered"; it was chewed, "snuffed" and smoked through "tabakos": If we can "drink a glass," can we not smoke a "*tabako*"?

The so-called American introductions are of less agrological interest, from the standpoint of origins, at least. The outstanding features may be briefly set down.

The mangosteen, the "world's best fruit," was brought in from Trinidad Botanical Gardens, in 1903; half a dozen other specimens have arrived since, but the two sturdy and very prolific seedlings, which the writer "nursed

along" with grave doubts at first for their success, have furnished many descendants since they began fruiting (about 1914). Some seven other Garcinias are here now, some rare species doing well.

One durian, about 12 years old, is in evidence.

Several litchis are promising well. A bulala (*Nephelium mutabile*) from the Philippines is in flower now; one of the best fruits. *Lecythis Zabucajo*, the paradise-nut, brought from Trinidad by the writer in 1924, is a magnificent specimen; and the Amazonian sapucaia (*L. usitata*) was introduced by the Porto Rico Experiment Station.

Of the Citri some 35 species and hybrids, not counting varieties, have been introduced since 1902 (when the Porto Rico Experiment Station was permanently established at Mayagüez); the more important ones are the king (*C. nobilis*), the satsumas and the satsumelos, the three kumquats, limequat, the Chinese Meyer's "lemon," several tangelos, the orangelo, and a fine lot of the little-known Philippine Citri—notably the kalpi (*C. webberi*), the tabog (*Chætospermum glutinosum*), the wampi (*Clausena lansium*), the Davao "lemon," the kabuyao (*C.* [*Papeda*] *hystrix*), the amontay (*C. hystrix* var.), the talamisan (*C. longispina*), etc.

Other rare Philippine fruits of recent arrival are the mabolo (*Diospyros discolor*), the ketembilla (*Dovyalis hebecarpa*), the lanzon (*Lansium domesticum*), the bignay (*Antidesma bunius*), the lemasa (*Artocarpus champedan*), the anonang (*Cordia blancoi*); several Philippine food species have been established 25 years or more—such as the jak (*Artocarpus integrifolia*), the asparagus-pea (*Psophocarpus tetragonolobus*), the Malay-apple (*Jambosa malaccensis*). The Surinam cherry (*Eugenia uniflora*) and the akee (*Blighia sapida*) are not yet appreciated.

A world-wide exchange of seeds, tubers and plants, begun by the Porto Rico Experiment Station in 1902, resulted in amassing a large collection of potential food-producing species. From Africa came the amatungulas (*Arduina bispinosa* and *A. grandiflora*) and the karanda (*A. Carandas*), the cola and a host of *Coffea* species.

The candle-tree (*Parmentiera cerifera*) from Panama is flourishing. The pejibaye, or peach palm (*Gulielma utilis*), arrived from Central America via Washington.

Some 20 varieties of Hawaiian and Oriental bananas and plantains have been introduced since 1902.

The writer had the honor of bringing the dasheen (*Caladium Colocasia esculenta globulifera*) from Trinidad in 1903, but it has not as yet by any means replaced the yautías; it has a shorter crop season, is less particular as to soil, yields better and "eats" better—but the *jíbaro* treats it as an interloper. Dr. David Fairchild once said it was perhaps the best single plant introduction—out of some 60,000 numbers—by the U. S. Department of Agriculture. Numerous other dasheens have been introduced to the Island's agriculture since 1902.

The excellent yampees (*Dioscorea trifida*) have been added to the two old varieties of this peculiar dwarf (1 to 2 meters, instead of, say, 10) type of yams; the new ones may produce larger roots but the yield is usually much less certain. Purple yam flour should some day find favor in high-class groceries.

Some 250 sorts of hybrid seedling sweet potatoes were tested in the Insular Department of Agriculture and Labor's Demonstration Farms; some of these (now named) and a few imported varieties are now in cultivation.

In 1924 a practically *always* spineless cactus, the "semaphore" (so-called from its long arm-like, horizontal "pen-

cas") (*Opuntia rubescens inermis*), was found in St. Thomas, American Virgin Islands; a food and fodder plant of merit; propagated by its "*fruits*" (not seeds).

The white sapote (*Casimiroa edulis* and or *C. tetramera*) may become an important new fruit. The voa vanga, or Madagascar tamarind (*Vangueria madagascariensis*), arrived in 1903.

Tea was brought in in 1903 but has never behaved properly. Many new Coffeas and cacao varieties came in through the Governmental Stations from 1903 to 1925. Several vanilla varieties have been added, and one is remarkably productive.

Many European vegetables, especially beans, salads and "kitchen herbs," were introduced between 1923 and 1926. The soya-beans came but have not given satisfaction. Five bonavists (*Dolichos lablab*) were brought from St. Thomas in 1924.

Many tobaccos have recently been tested and distributed; one outstanding hybrid has been created *in loco*—the "ceniza."

The most important forage plants of recent introduction are: elephant grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*), Philippine adlays (*Coix lachryma-jobi*) in variety, and kikuyu (*Pennisetum clandestinum*). Alfalfa rarely succeeds here.

By far the most important crop plant introductions under the American régime have been the new high-grade sugar-cane varieties; these have come largely from Java, but several are locally made hybrids, and a few of much merit from Hawaii, British Honduras, British Guiana and Barbados; some 500 sorts have been tested and many distributed to the 40 "centrals." The famous "uba," which arrived in 1917 from Argentina, virtually saved the industry from the "mosaic disease," but has recently been superseded by the superior Javan hybrids.

Comparatively few introductions have been made since the stringent Federal "Plant Quarantine" was added to the apparently efficient "Insular Service" in 1925, and the present outlook for the entrance of the 200 or more food plants which *should* be brought to Boriquen is deplorably depressing: the rearward perspective illuminant, the forward nebulous.

# THE EFFECT OF THE MACHINE AGE ON LABOR

By SUMNER BOYER ELY

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We constantly hear to-day that the labor-saving machine is an economic wrong, that it has been displacing more and more workmen until unemployment has culminated in the present deplorable situation. It is said that the machine has so speeded up industry that overproduction has resulted; and this is believed by many to be the major underlying cause for the present world depression. It is further asserted that the industrial wage-earner in the past constituted the market; now, having lost his purchasing power, our markets have been destroyed; and that if we do not stop inventing we must make some radical change in our methods of distributing wealth. Otherwise the machine will ultimately destroy civilization.

These are severe indictments to bring against the labor-saving machine; and indirectly against science, for the advancement of science made possible the so-called industrial revolution. It is therefore worth while to analyse and investigate these charges in some detail.

### The Beginnings of the Industrial Revolution

It is difficult to say just when the industrial revolution had its inception. It is true that the ancient world had a few stones for grinding grain that were driven by a sort of crude water wheel; and it is also true that the genius of Leonardo da Vinci produced some remarkable mechanical contrivances. Yet, what we understand as the industrial age really began with the advent of the power-driven machine tool; some hundred or at most hundred and fifty years ago. It is a strange thing that it is only yesterday in man's civilization that such machines have come into existence. Why they did not develop sooner it is difficult to say. Perhaps we did not possess satisfactory metal or other materials; but whatever the cause was it remained for the later part of the eighteenth century to see the first power-driven machine tools.

### Labor Displacement and Adjustment

The old-time shoemaker and his passing is a good illustration of what machines have done to old established trades and industries. In the large shoe manufacturing plants of to-day there is not a man who could make a pair of shoes. Pieces of leather are dropped into various machines, removed and placed together and again put into still other machines, until finally a finished shoe is produced. The shoemaker no longer exists; he is replaced by a machine-tender of little or no skill. There has been what the engineer technically knows as a "transference of skill." The skill possessed by the old shoemaker has been transferred into the machine and the man's skill is no longer required.

But in addition to this transference of skill, the production has been enormously increased and a few unskilled men can now produce as much as a whole community originally. The result of the machine has been twofold, to degrade labor and to require less labor for the same production.

In the early days of the textile industry in England, when automatic machinery was introduced by Jenney, Arkwright and others, the skilled workman found himself displaced by women and children and the cheapest kinds of labor. The scramble for work, the abuse, mis-

ery and terrible suffering that resulted are well known and form a blot on the page of civilization. If a man has spent many years in learning a trade and become highly expert in doing certain things it is not easy for him to discard all this and start anew to acquire another trade. No wonder the skilled man feels bitterly against the machine that has put a boy in his place. Furthermore, his pride will often prevent him doing what he considers inferior work, and at best it is difficult for him to adjust himself to the new conditions. In fact many men never do adjust themselves and it often takes a new generation of workmen before labor can accommodate itself to the new order.

This applies not only to highly skilled labor, but is true to a greater or less extent of all labor, skilled or unskilled. A few years ago, a large steel plant near Pittsburgh, while making certain machinery changes, needed a gang of laborers for a few weeks to pile pig iron. Arrangements were made with a labor agency in Pittsburgh and a car-load of men was sent to the plant. Most of these proved to be Italians who were accustomed to using a pick and shovel. As soon as they saw what was wanted and that they were not to use pick and shovel, most of them refused to work and returned to Pittsburgh. The wages offered were particularly attractive, as the company needed the men badly, and it would seem as if digging with pick and shovel was about as hard physical work as piling pig iron. There seems to be an inertia in labor so that the workman does not easily and freely change from one kind of work to another.

Labor adjustments due to the introduction of machines are taking place about us continually. The reason we do not see or hear much of them is because the industrial field, since the time of Jenney and Arkwright, has grown to such immense proportions. An ordinary improvement in machinery is such a common every-day happening that unless it is of a very spectacular nature it attracts no public attention and goes entirely unnoticed. And yet the effects are always the same, and some workmen are likely to be displaced and forced into other occupations. The very name "labor-saving machinery" indicates that some particular kind of labor is no longer needed.

### Machine Production of Wealth and its Effect on Labor

But what about the machine's effect on the general community and its indirect effect on the particular group of men it has displaced? Before 1850 this was a world of deficits, according to one of the officials of the United States Steel Corporation who has compiled some figures on this subject. About all a man could then do was to produce enough to support himself and one other. Today man's productive power has so increased, through the use of machinery, that he can support himself and ten others. This has become a world of surpluses. During our Civil War the machine reaper was invented and first put into use. It solved the food problem for the armies at the time and has made the United States a great exporter of wheat.

Machines have produced goods in such abundance and so cheaply that all classes, including the machine laborer himself, have shared in the general prosperity. Never before in the history of the world have wealth and comfort been so wide-spread and enjoyed by so many different classes of men.

Due to the great growth of industry, which has come about through mechanization, an enormous field has been opened to the workman. Where only a few skilled men could be employed before, now great numbers of unskilled and semi-skilled workmen are in indus-

try. All this opportunity and creation of wealth has raised the whole laboring class, and while a few may have suffered the benefit to the whole has been tremendous.

The laborer of to-day lives better than the lord of yesterday. Properly heated and ventilated living quarters, sanitary plumbing, good food, sewing machines, telephones, electric light are within the reach of nearly every one, to say nothing of automobiles, books, movies, etc. Why, some two hundred years ago, instead of flooding a room with light by turning an electric switch, a smoky torch or at best a spluttering wick was all that was possible.

The cost of living is an indefinite matter and depends on the standard of living, so that comparisons over long periods of years are not satisfactory. It is of interest, however, to see that the United States Department of Labor's index number of the cost of living in the United States doubled from 1914 to 1930, while during the same period the wages in the textile, shoe, lumber and other highly mechanized industries increased some 300 per cent. on the average. The wages of all industries taken as a whole do not show as great an increase as the mechanized industries but, taking into account the cost of living, will average somewhere around 35 per cent. gain for the period 1914 to 1930.

The National Industrial Conference Board surveys show that the volume of products produced in 1914 would have required but seventy per cent. of the number of workmen had the same volume been produced during 1926. Furthermore, the wages would have shown an increase of from 50 per cent. to 100 per cent. and in addition the working day would have been shorter. Such figures indicate that even over a comparatively short period of years there has been an increase in the intrinsic wealth and comfort of the industrial worker.

THE IMPROVED CONDITION OF LABOR

Along with this physical betterment has come a spiritual release. In ancient times the slave was just so much absolute property, owned body and soul, to be whipped, killed or disposed of as his master saw fit. During the middle ages there may have been a slight improvement in his condition but he was still a serf, and even down to the beginning of the industrial revolution and the start of the factory system labor conditions were very bad. But as the machine developed so did the workman. We do not always remember what an enormous advance labor has made, and that the machine instead of making him a slave has freed him. The machine, too, has relieved him of that terrible physical exertion that a civilization built on slave labor required. The thousands of straining men are no longer necessary to erect a pyramid or a Roman aqueduct. It is often said of the machine that the repetition of the same operation day in and day out makes a workman lose all initiative and responsibility, and that he becomes a mere automaton. Yet it is hard to see why it is more deadening to operate a steam shovel than it is to dig with a hand shovel, or to control a steam hammer than to swing a sledge. A certain job in one of our eastern machine tool shops required a laborer to simply tighten bolts. Even the nuts had been placed on the bolts and all required of him was to draw them up with a wrench. This particular workman had steady work, adequate pay, short hours and a comfortable shop in which to work. If you talked with him you would find that he was not only contented but took a certain sort of pride in how efficient he had become. A man of imagination could not endure such work; but there are many men who prefer something of this kind where there is no tax on their mentality. Perhaps some day we will be able, by psychological or other test,

to sort men and learn for what particular type of work they are fitted.

### The Over-production Myth

There is a popular explanation of this present depression which is always advanced during any industrial upset. It is supposed to be conveyed in the high sounding term "over-production." The older economists used to distinguish between the two supposedly antagonistic theories of over-production and under-consumption. We do not hear much of under-consumption to-day. Like that monstrosity, the old economic man, it seems to be dead. Over-production and under-consumption are a mere jangle of words and mean the same thing.

With the advancing machine age and its ever greater production, there seems to be an underlying vague notion that the amount of necessaries, comforts and luxuries which a community can consume is a definite and fixed amount, and that if this be exceeded men will not know how to use the surplus. This is an absurdity. Are there any men who could not easily spend double or triple their incomes? We can own two automobiles as easily as one, we can get a new one every year or every six months. Why cannot a man own ten pairs of shoes as well as one? With houses, clothes, costly foods and what not, any civilized community could double or quadruple its consumption of wealth. What is prosperity but a great increase of luxury, when all the non-essentials such as soda fountains, candy shops and the rest are flourishing?

The fact that during this depression we have too many houses, too much idle capital, storehouses full and men willing and anxious to work means that our economic system is at fault, not that we have produced more than we can consume. If production in one line is carried on until there is an accumulation of vast stocks of unsalable goods we have partial over-production. It may be that this particular industry then thinks best to curtail and men are thrown out of employment, which may disturb the delicate balance of economic relations. It may cause serious trouble; it may not. If it comes at a time when conditions are ripe for a depression it might perhaps precipitate it by giving the initial push. How can anyone say, of this infinitely complex economic system of ours, that any one factor has caused this depression? In the last analysis the depression is psychological and depends on the disposition of people to buy or sell, but the causes which influence this disposition may be legion.

No one doubts that there is such a thing as partial over-production; but this is not the machine's fault, it is due to the bad judgment of the machine's owner and might occur in a non-machine civilization. To condemn the machine because it produces too much would be akin to scrapping all steamships because there has been an occasional accident. Partial over-production there may be, but a general over-production of wealth is an impossibility.

### Some Statistics

Is technological unemployment throwing men out of work faster than they can be absorbed in other or new industries? Is the machine destroying the man and forcing him into a permanent bread line?

An examination of the census reports shows that in 1890 the total number of people in continental United States gainfully employed was 36.1 per cent. of the population. By 1930 this number had risen to 39.8 per cent. This includes everybody in all lines: agriculture, industry, business, professional, public and domestic service, etc.

We find that during the ten years from 1920 to 1930, sixteen men left agriculture, four left industry and one min-

ing—a total loss of twenty-one men per thousand of population. Against this, transportation gained seven men, public service gained one, domestic service seven, professional service seven and miscellaneous three—a total gain of twenty-five men. The balance gives a net gain of four per thousand of population. Whatever interpretation we may choose to put on such figures, they at least seem to indicate that employment is increasing faster than population.

Confining our figures now to manufactures only, leaving out agriculture, mining, transportation, public service, fisheries, etc., we find from the census report that forty-two persons per thousand of the population were employed in manufacture in 1850. By 1900 this number had become sixty-three and by 1925 it was seventy-three per thousand population. These figures are perhaps not as definite as we would like, but they indicate, as we would expect, that the United States has become more and more of a manufacturing nation; and that the increase of the number of jobs in manufacturing pursuits has been greater than the increase in the population. If figured out it will be found that the population increased about five times from 1850 to 1925, whereas the number of wage earners, which can roughly be taken as the number of jobs, increased some eight and one half times.

The influence of mechanization on employment is indicated in the following figures obtained from the census. In the shoe industry of the United States in 1900 there were 153,600 persons employed; by 1925 the number was 206,992. During these years when the industry was highly mechanized the number of employees did not become less. Again, in the printing industry, also highly mechanized, in 1900 there were 162,990 persons employed, and in 1925 the number was 251,272. It will be found with most industries, that as mechanization takes place there is an increase in the number of wage earners along with it. These figures may be accounted for by the growth of the industry to meet the demand caused by the cheaper prices that the manufacturer has been able to ask. Then, too, a certain amount of labor is always required, even when mechanized. In some cases machines have been introduced with little or no displacement of men; the effect of the machine being a greatly increased production per man.

### What the Future May Bring

Consider for a moment a continuous rod or bar mill in one of our large steel plants. About all the labor required is to manipulate the levers that operate the tables and guide the hot steel billet into the proper rolls, with possibly a little attention when the product comes out of the mill to see that it goes to the proper destination for shipment, storage, etc. In other words the labor is almost nothing and at an irreducible minimum. Mechanization has already reduced the labor so that no more can be saved. In many of our industries we have already reached this point or are fast approaching it. If we keep on mechanizing all our industries, it is only a question of time until we reach a limit.

What is true of labor is true of power. One heat unit can produce 778 foot pounds of work, when completely utilized, and no more. Our boilers to-day are utilizing 80 per cent. or 85 per cent. of the heat supplied to them; which means there is only 15 per cent. or 20 per cent. further improvement possible. Our prime movers also have about the same possibility of advance before reaching the efficiency of the ideal cycle.

Then the law of diminishing returns will retard our advance as we approach the limit. A few years ago when we

were on the top wave of prosperity we heard that there was no restriction on production, that it was possible to speed up the rate of increase higher and higher. The law of diminishing returns was either classed with the economic fallacies of the past or else ignored entirely. Now that we have gotten over the optimism of the boom years and look sanely at the production of wealth, we realize that this law must check us economically as it always has. Every engineer knows how it becomes more and more difficult to increase efficiency, how each saving is a little harder to make than the one before.

Science will progress in the future probably faster than in the past, but so far as labor is concerned science is powerless to reduce what is already reduced. And here is the crux of this whole situation. When we have once become thoroughly mechanized labor can no longer be affected by the machine and must adjust itself as it did before the age of technological unemployment. From this point of view we have made a mountain out of a mole-hill and become unnecessarily disturbed about something that will adjust itself as time goes on.

Of course we can never do without labor as has already been said. There will always be an irreducible minimum. No matter how automatic a machine may be, somebody must start and stop it, see that the right materials are fed to it, oil and adjust it, and a certain amount of attention will always be required. It is quite reasonable to suppose that science may make discoveries and extend our knowledge in ways that are undreamt of to-day, which will bring about the development of a vast number of new machines. Great numbers of old machines will be needed to meet the demand as the population grows. What with the increased numbers of machines in old fields and large numbers of machines in new fields, labor will be provided with great opportunities for employment.

This is only another way of saying that if the census figures are to be believed the number of wage earners will increase faster than the population, probably for many years to come.

# SCIENCE SERVICE RADIO TALKS

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# INDIVIDUAL DIFFERENCES IN MENTAL GROWTH

By Dr. FRANK N. FREEMAN

PROFESSOR OF EDUCATIONAL PSYCHOLOGY, UNIVERSITY OF CHICAGO

MOST people believe that the precocious child is likely to come to some bad end. If he does not have a complete mental breakdown he at least reaches the end of his development in early youth and falls behind his slower-moving companions before they have arrived at complete maturity. The prevailing opinion of psychologists is just the opposite. According to most psychologists, the child who develops rapidly also continues to develop longer than does the slow-growing child. According to the popular view, the slowness in development is compensated for by a longer continuance of growth. According to the prevailing scientific view, however, the precocious child has a double advantage, and the slower-growing child a double disadvantage. It is very important that we should know which of these views is correct.

It is the business of science to investigate such a difference of opinion as this and to determine which is in accordance with the facts. Since the advent of mental testing, psychologists have studied their results with a view to finding the answer to this and other questions regarding the mental growth of the individual.

Our prediction of the ultimate level of the child's mental ability and the kind of education that we prescribe for the child will be governed by our opinion on the question. If we think, for example, that the child who is developing more slowly in the earlier years is destined to fall farther and farther behind his more precocious schoolmates and to stop developing altogether at an earlier age, we will advise him to take a course which does not demand the same ability and does not extend over so long a period as if we believed that this child might at least keep pace with, if not partly catch up with, his more rapid companion.

Practically all the evidence on this point, which has been available up to the present, has been based upon mass scores from groups of children of different ages. Very few studies have traced the development of the same children from childhood to maturity in order to see what actually becomes of the children at different levels of ability. Certain difficulties arise in the interpretation of the scores from different groups of children at the successive ages which can not be gone into in this brief talk. It is evident, however, that we get a more reliable indication from following the course of development of individual children. This method of study has recently been applied to several hundred children in the elementary and high school of the University of Chicago.

After a period of ten years, a sufficient number of continuous records have been obtained to enable us to throw new light upon some of the problems of individual growth. On the particular problem which I have mentioned, a study of the growth of individual children does not confirm the conclusion from the

earlier studies of mental tests that the slower children reach the end of their mental growth earlier than do the faster children. We are not able to report on mental defectives or even on children of low normal intelligence, but we can compare the growth of those who are somewhat below the average with the growth of bright children. We are able to show, for example, that some children, who get a slow start and are near the bottom of the entire group of pupils in the earlier years of the elementary school, continue to advance steadily well into the college period. In other words, there are some individuals who make a rather low standing during childhood because they get a slow start, but who rise to a higher level in later adolescence because they continue at a steadier pace than some of those who get an early start.

If this were true only of a few isolated examples it would not be of great educational importance, since our educational policies must be based upon the majority rather than upon a few exceptions. In order to find out whether such a case is only an infrequent exception or whether it represents the rule, a grouping was made of about 100 children for whom we had continuous records from eleven to sixteen years of age. We also had records on most of these children at ten years and at seventeen years. This entire group was divided into three groups based upon their scores on the test during the middle years. The average curve for each group was then drawn. These average curves indicate that there is a real difference in the mode of development of the bright and the slower pupils. They also show that the popular opinion concerning the growth of bright and duller children is more nearly right than is the opinion of most psychologists.

The children in the bright group begin to advance at an accelerated rate at about ten years of age. Their curve then advances more steeply for two or three years than do the curves of the other two groups. The curve of these bright children, however, begins to slow down sooner than do those of the others. None of the groups reach their complete development by seventeen years of age, so that it is impossible to say how far apart they will be when their growth reaches its final level. By seventeen years of age, however, the upper curve is slowing up, whereas the lower group of children are continuing to advance at an undiminished rate. This makes it seem certain that the pupils in the lower group will partly catch up with those who took the highest rank during the childhood period.

It would be a mistake to infer from these facts that we are unable to predict at all what the child's later mental attainment will be on the basis of his intelligence or his educational achievement in the elementary school or in the early part of the high school. Such prediction is possible, provided we allow a considerable margin of error and also provided we do not discount the possible future development of the pupils who make a moderate record in the early years. Our findings show that these pupils who are at the middle or even below the middle of their class will continue to advance as long, if not longer, than will the brighter pupils of the class. Some of those who make a relatively poor showing in the earlier years will indeed gain so much on their faster comrades that they will make a decidedly better showing in high school or in college than we might have expected them to make. On the average, of course, pupils in the lower half in the elementary school will remain below in the high school, and few if any of those in the lower quarter are likely to go much beyond the high school; but some pupils in the lower half of their elementary school classes may in the end outstrip other pupils who outshine them considerably during the childhood period.

In our prediction of pupils' later educational attainments and in our advice to them concerning their educational choices, we must make allowances for this fact and we must also give weight to the factors of character and purpose. We have been too inclined to think that the odds are all in favor of the bright and precocious child. We must now recognize that our prediction is not quite so certain as we thought it was and that the slower child may have possibilities of attainment that we have been inclined to deny him in the past.

We could, perhaps, make a more accurate prediction of the course of mental development of children and of the degree of ability they are likely to attain, if we knew more than we do about the conditions which govern such development and ultimate attainment. We know enough to be able to say that development is governed partly by inner forces and partly by outer forces, but we have not been able to measure these inner and outer forces or to say just what proportion they bear to each other.

Some psychologists have thought that mental development is closely bound up with physical development, so that, for example, if a child's body matures early his mind will also mature early, and *vice versa*. If this is true, we ought to be able to use various physical indices, such as growth of teeth, growth of the wrist bones, and signs indicating the onset of puberty, as indicating the proportion of his mental development which an individual child has attained at a particular age. One check on this theory is to compare boys and girls. It is a well-known fact that girls reach physical maturity about two years earlier than do boys. If mental growth follows physical growth girls should attain their full mental stature two years before boys. Some psychologists have believed that this is the case. Our findings, however, do not show that girls reach intellectual maturity any earlier than do boys.

We must distinguish between ability and certain other mental characteristics. There is no question that the girl matures more quickly in her attitudes toward people and in her ability to manage herself in social situations; but this is not the type of mental development I am talking about. I refer rather to what we call intellectual development, or the development of ability to learn and to think, the ability which is required for success in school and college. In this boys and girls seem to advance at the same pace and to continue for the same length of time. If we compare different boys with each other, or different girls with each other, the same thing holds. Those who mature early in body do not mature much sooner in mind than do those who mature late. The difference is so slight that it is hardly noticeable in comparison with the large differences which are due to other causes.

As yet we know very little about what these other causes are. One school of psychologists thinks that they are chiefly or almost entirely internal, that is, that they are a part of the person's inborn or inherited nature. According to this belief, a person's future mental growth is all laid out for him even before he is born and nothing which happens to him, his education or training, his home care, his friendships or his cultural opportunities will affect the course that it will take.

This is an extreme view, and we have good scientific evidence that it is one-sided. We have found, for example, from a study of duplicate or identical twins who have been reared apart, that they differ from each other in ability about twice as much as do identical twins who are reared together. We must conclude, then, that the course of mental growth will be influenced for good or ill by the kind of education the person receives. We can not predict perfectly what mental stature a person will finally

reach or when he will reach it, partly because his growth will be influenced by his training.

These facts are encouraging to the children and to the parents and teachers of children who are not brilliant in their early years. They do not, by any means, indicate that we can make geniuses out of numbskulls, but they do indicate that it is worth while investing educational efforts in pupils who do not seem especially promising, since they may turn out better than their early attainments would lead us to expect.

# THE EFFECT OF WORRY ON DIGESTION

By Dr. A. C. IVY

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ONE hundred years ago, Dr. Beaumont, an army surgeon located in northern Michigan, had as a patient a trapper whose name was Alexis St. Martin. The trapper had been shot in the upper abdomen, a hole being made in the stomach. When the wound healed, the opening in the stomach remained open, so that Dr. Beaumont could look into the stomach and see its lining. Dr. Beaumont found that in the presence of fear, anger and whatever disturbs the nervous system, the lining of the stomach loses its healthy appearance and the secretions are greatly decreased or stop flowing. Dr. Beaumont also found that when his patient, Alexis St. Martin, had a quarrel, the movements of the stomach were not normal.

These stories have been duplicated many times in the experience of physicians. Indeed, I am sure that many of you have felt a lump in the throat or beneath the breast bone, when you were grieved over the loss of a friend. This feeling of a lump was due to a spasm of the muscle of the gullet, or esophagus. Or, it may be that when you have been angry or especially worried about something, you felt a lump or pain in the region of the stomach; or it may be that your colon has become more sensitive or irritable than normal. In some people who are particularly sensitive, even the worry or anxiety associated with a business engagement, the making of a speech in public, the fear that a dinner party will not be a success, is sufficient to cause digestive disturbances. I believe that you would like to know why these disturbances occur and whether anything can be done about them.

It is the function of the physiologist to find out the *why* and *how* of such disturbances in the human body and to suggest what should be done to correct them. This, of course, is not always easily and quickly accomplished, because of the complexity of the living body. As a young man, I remember that I visited a great manufacturing plant. I was awed and mystified by what I saw being done. Yet when we realize what wonderful processes occur in our digestive canal, industrial processes are much less awe-inspiring. All kinds of foods enter the digestive canal and are subjected to chemical and physical processes. Digestive juices are secreted which act on the foods in a special way, rendering them capable of being absorbed and of carrying on the processes of life. In a modern industrial plant, each department has a special function to perform. In the digestive system, the stomach, pancreas, liver, small and large intestine have certain functions they must perform. The food is held in one part, the stomach, for example, until its work is completed and is then passed on

to the next part. If these parts do not perform their functions properly, symptoms such as nausea, vomiting, pain, etc., result. If one part does not work properly, the other parts are affected.

All parts of the digestive canal or tube are made up of muscle fibers and glands. The glands secrete digestive juices, or chemical reagents, which liquefy and decompose the food. The muscle fibers churn the food with the digestive juices and move the food along. The muscle fibers and glands are connected with the brain by nerves. The nerves conduct messages to the muscle fibers and glands. In some instances the nerve impulses cause the muscle fibers to contract, in others to relax, or they cause the glands to secrete juice, or they may stop them from secreting juice. Obviously, then, the type of activity going on in the brain may have an influence on the movements of the stomach and intestine and the formation of digestive juices.

In susceptible individuals, only a minor degree of worry or anger may prevent a flow of gastric juice. I shall give two examples. When a hungry dog smells or tastes meat, gastric juice is formed. This is called a psychic secretion. The smelling and tasting of the food excites certain parts of the brain, and nerve messages pass to the stomach and cause it to secrete. If the dog does not like cats, and if we show him a cat, a psychic secretion of gastric juice will not occur. If we start a psychic secretion by permitting the dog to taste meat, and then show him a cat, the secretion will stop. If we teach the dog to like the cat, then we may show the cat to the dog without stopping the psychic secretion. It is difficult, however, to teach some dogs to become accustomed to cats. Similarly, it is difficult for some men and women to learn how not to worry. As the second example, I have in mind a young man who as a boy accidentally swallowed some lye. His gullet or esophagus was burned so badly that it closed up. In order to keep the boy alive, the surgeons made an opening into his stomach through which food could be placed into the stomach. When a young man, he went to a university and said that he would like to serve as an experimental subject. Like the dog described above, when this man tasted and smelled food, much gastric juice was formed. One day he consented to demonstrate this fact to a group of doctors. But he was nervous and excited and the demonstration did not work. He later became accustomed to making public appearances and the demonstration worked every time. It may interest you to learn that if a person is hypnotized and then is told that in front of him on the table is a beefsteak and then he goes through the motions of eating the steak, the stomach of the hypnotized subject "waters" gastric juice just as the mouth "waters" saliva when we actually see a good beefsteak.

The movements of the stomach are likewise influenced by the activity of the brain. Strong emotion may cause a part of the stomach to contract so forcibly that severe pain results, as in the case of the young lady I told you about. But worry generally retards the movements of the stomach and the food may lie in the stomach for a longer time than normal. For example, when one studies the movements of the stomach in cats and dogs, the animals must be handled very gently in order to observe normal movements and emptying of the stomach. Several years ago I observed that when medical students are given a written examination in physiology, the emptying of their stomach is prolonged an hour or more. In this connection, I should point out that the stomach has a front and a back door, so to speak. The foods enter through the front door, and after being partially liquefied, the move-

ments of the stomach force them out through the back door. Now, if the movements of the stomach are not strong and if the back door is closed more tightly than normal, the food will remain in the stomach longer than normal. Also when one is anxious and worried, one is generally not careful how thoroughly the food is chewed, and large lumps of fruit, vegetables and meat are swallowed. Now, when one is worried, the back door of the stomach may be closed tightly and these lumps of food, being difficult to liquefy, may remain in the stomach many hours.

From what you have been told, it is apparent that if the food is appetizing, if the surroundings are pleasant and the frame of mind so that the food can be enjoyed, the digestive organs are prepared or girded for action and function perfectly. So there is much truth in the statement, "Laugh and grow fat; worry and grow thin."

Emotion, anxiety and worry not only affect the movements of the stomach but also movements of the colon. Certain movements of the colon may be stopped and others increased by worry. Worry and nervous tension generally cause the colon to become more irritable and spastic and produce colitis. You all know that the last part of the colon is under the control of the brain to a very large extent, and good and bad habits may be formed in regard to its emptying.

Another interesting and important fact is that hunger is caused by vigorous contractions of the stomach. If one fasts for twelve or twenty-four hours, pains are felt in the region of the stomach which are caused by the vigorous contractions of the stomach. If one is anxious and worried, these contractions may not occur, and appetite is frequently absent. Hunger and appetite increase the rate of digestion and the emptying of the stomach. Some so-called "nervous" children do not eat because they are worried and have been unduly excited by nagging parents or by some story they have heard or some picture they have seen.

It would be wrong for me to give you the impression that anxiety or worry is the cause of all digestive troubles, because it is not. The facts that I have pointed out do show that peace of mind and comfort are very important for normal digestion. These facts also show that mental discord and worry disturb normal digestion and may serve as the background for the development of certain diseases of digestion. In this connection it is a fact that deaths from gastric ulcer have increased 25 per cent. among white men since the start of the depression in 1929. And it is certain that altered physiology of the stomach is very likely concerned in the cause of gastric ulcer. Every physician recommends as a part of the treatment of gastric ulcer and of colitis, diet, rest and freedom from worry, or a vacation.

What is the solution of the problem I have outlined? It would be easy for me to say that the solution is to stop worrying and to avoid things that cause worry, strife and care. But this is impossible for a busy man or woman with responsibilities on his or her shoulders. But I think there is a way out for even the busy man and woman. First, we must teach ourselves to forget our worries and responsibilities for brief periods at least. Every one knows that a sense of responsibility is acquired and may become a habit. I think it is an excellent habit, unless carried so far that we permit it to interfere with our health and the happiness of others. It is good to take oneself seriously, but not so seriously that it interferes with one's health and sense of humor. Now just as we learn or train ourselves to shoulder re-

sponsibilities, we can train ourselves to forget them. Some people say they can not do this. That means only that their "worry habit" is very bad and that it is going to require much effort to conquer it. But it can be done. Second, we must learn how to relax our body muscles at will. The learning to forget to worry for a brief period and to relax the body muscles are processes which are closely associated. When one is worried, the body muscles become tense and may remain tense even when sitting or lying down. The ability to relax and rest for brief periods under any circumstances may be acquired and learned. Fresh air, exercise and non-competitive play assist one to forget and to relax. When we sit down to eat and even for a brief period before and after eating, we should forget our worries and relax our muscles. While eating, we should think of pleasant things, enjoy the food and chew it thoroughly. And third, during a day fraught with business worry, wrangling, mental or nervous strain, or at times when it is impossible to forget and to relax, we must either postpone the meal until strong emotion has passed, fatigue has lessened, calm has been restored and appetite has returned, or we must eat lightly of foods that are easily digested and emptied from the stomach such as soups, cereals, puréed or mashed cooked vegetables, etc., or what physicians call a soft diet. In this connection we must bear in mind the fact that raw milk is changed into a solid in the stomach and that it is better for some people to mix the milk with toast or cereal.

Let us remember that our stomach should be a servant and not a master. We should not spoil it by too much attention, neither should it be ruined by wilful neglect and abuse. "Better is a dry morsel and quietness therewith than a house full of feasting with strife."

# GOLD

By SCOTT TURNER
DIRECTOR, UNITED STATES BUREAU OF MINES

Probably the word gold is used more frequently in the language of metaphor than in direct reference to the metal itself. It will be found employed thus many times in almost any book, and it recurs constantly in our daily speech. We refer to a golden age, a golden hour, a golden memory, the golden rule, and to silence that is golden. A golden fleece inspired the Argonauts to adventure; a golden edict granted rights to an oppressed people. There is a golden mean of conduct; the word of an honest man is as good as gold. There are golden voices, opportunities and opinions.

Things are said to be as pure as gold; a voice resembles liquid gold; worthy people have hearts of gold. Many uses of the word refer to its color and metallic luster, as golden sunset, golden hair, golden grain. Thus the word is employed to suggest not only a lustrous yellow metal, but purity, value, worth, merit, perfection, beauty and other similar qualities that indicate the high esteem in which this element has long been held. Yet gold is a metal, as iron, copper, lead, zinc, aluminum and tin are metals. It resembles all of them in a general way, some of them closely; even its color can nearly be matched by brass, a mixture of copper and zinc, or by bronze, a compound of copper and tin.

Why, then, is gold so valuable and so important? Certainly not because it is yellow, heavy, malleable, ductile and lustrous. The explanation is that this

one metal is endowed with a particular combination of properties that made possible its ancient discovery, and led to its early utilization, to wide-spread longing for its possession, and finally to its use as a measure of worth and as a means of storing value for the future.

The human desire that results in gold being so highly prized is as old as history. It has persisted through thousands of years. During perhaps a hundred centuries, while nations rose and fell, as conflicting philosophies, religions and the languages in which they were expressed, waxed and waned, mankind agreed in this at least—every one wanted gold. This desire was paralleled in intensity and persistence only by the craving for food and other necessities of life, for which gold could be exchanged at will.

Throughout the ages, can man have been mistaken in his esteem of gold? Was he infatuated and beguiled by its yellow glitter, though not by the gleam of brass and bronze? Assuredly not. Though he was not aware of the numerous factors that jointly created gold's value, he was competent to judge whether a little gold would serve him as well, or better, for certain purposes, than many times its weight of brass or bronze, and he decided that it would.

One reason for his choice was his observation that, with gold, he could buy not only brass or bronze, but any other commodity, whenever he chose to do so, and that he need not hurry to trade it away, as he did when he invested in perishable commodities or those that cost something to store and keep; gold gave command of time. Man knew that until he decided what should be bought with this gold, he could secrete it or transport it more easily than other commodities of equal worth. In his purse, he could carry enough to pay for all the grain many beasts of burden could carry. Gold was so indestructible that, if buried, it would not rust; even if melted by fire, it would still remain the pure bright metal. If its possessor traveled to a distant land where people spoke an alien tongue, they would nevertheless understand the worth of the gold he offered them in trade.

Gold was more stable in value than other commodities; all others varied more widely and more rapidly in price. Oversupply of many of them, due to seasonal production, was followed by depletion and dearth, because they were gradually consumed. The effect on prices is illustrated by the low cost of grain after harvest and the high price before it, or by the charge for fish after and before an unusual catch. Gold, however, was neither consumed nor supplied in great excess. Withdrawals and returns of gold, from and to circulation, tended to balance in the long run; if its value began to decrease because of oversupply, export of gold to other places, where it would buy more, tended to occur because it was so easily transported.

Hence, its price was fixed less by local than by wide demand, and it was, therefore, more stable in relation to the mean of prices in general. The superior steadiness in the value of gold was naturally prized by the prudent, who were saving for the future and for old age. Just as insurance funds are invested to provide security above all else, so men of the past who wanted a store for future use sought gold in preference to other commodities as the means to this end.

For these and similar reasons, it was not illogical that man used gold long before there was money. It was easily beaten into the desired form, and its softness helped to save it for special purposes, since it was not hard enough to be generally useful and was therefore reserved for ornaments. As its esteem for personal decoration grew, it naturally went from the weaker to the stronger, from the tribesman to the chief, and so it was hoarded and saved.

Almost precisely the same circumstances applied to silver after its discovery, which was later than that of gold; both metals had been employed in barter and trade, as preferred mediums of exchange, long before the first coin was made, and ages before our present monetary systems began to evolve from the use of gold and silver money. At an early date, however, much larger stocks of silver than of gold must have accumulated, because the price of the former appears to have been only a fifth of the price of gold when mining of silver was begun by the Athenians.

The monetary systems of the present have marvelous social utility, but they should not be deemed more remarkable than the automatic evolution of exchange in earlier times through the use of gold and silver, from which financial methods were, in turn, evolved. The early basing of commodity-exchange upon metal was induced by prehistoric man's discovery of so-called placer deposits of gold in stream-beds of Asia, Africa and Europe. Indestructibility and high specific gravity of the metal were important factors. In many such deposits, the gold could be seen readily, as it was in 1848 when discovered in California. Placer gold may occur in tiny flakes or grains, or in nuggets of considerable size. One nugget found in California weighed nearly 1,600 ounces. Another in Australia exceeded 2,000 ounces; it was revealed by the rut made by a wagon wheel. A savage would hardly ignore such a nugget, even though he had no previous knowledge of this metal. Leo Africanus, writing during the Middle Ages of a king who lived on the Gold Coast of Africa, described him as using a huge nugget of gold as a seat.

Gold is identified more readily than other metals, because they usually occur in nature in chemical compounds; the property of gold that keeps it bright and free from tarnish likewise prevents it from passing into solution, and from combining readily with other elements. It is relatively imperishable. That is why it is found concentrated in placers as a bright native metal. Glittering objects catch the eye of animals; gleaming gold must have attracted instantly the attention of primitive man. It is presumed to have been the first metal discovered by human beings, though there are no records to prove it. We only know that gold was already established in use and in the esteem of man when history began.

Two other things about gold have probably been important. It is widely distributed about the earth's surface, as it occurs to some extent in nearly every country. This would tend to make all peoples acquainted with it sufficiently to account for its wide-spread acceptance. The other is the fact that nowhere is gold extremely abundant. Most of the time, before the present century, the increase in accumulated stocks of the metal throughout the world proceeded slowly, and the amount added each year was not sufficient to disturb the value of gold, especially as the addition would tend to be balanced somewhat by growth of population and by expansion of trade. The latter accounts for the ready absorption of enormously expanded production of gold in recent years, without pronounced effects in inflation.

The whole fascinating story of gold, covering its occurrence, discovery, production and use, its influence upon progress and civilization, on history, on the struggle of man to conquer his environment and upon his mind, oriented to gold as a symbol of individual, national and social well-being, concerns an astonishingly small amount of this precious metal. All the gold produced in the world since the discovery of America, which probably exceeds vastly the total in the ages before, could be contained in a cube measuring less than 40 feet on each edge. In weight, this amounts to

only about 38,000 short tons; over fifty times that weight of copper was produced in the single year, 1929.

Think of the work and effort, the rivalry and strife, the injustice and oppression, the schemes and plots, the quarrels and fights, the battles and wars that have been involved in the accumulation and preservation, the winning and owning, of this relatively small amount of yellow metal!

A one-inch cube of gold is worth about \$210; if an infantryman in the United States army carried the weight of his standard battle equipment of 71½ pounds, in gold, he would have \$21,600 worth—enough for a cube 4.7 inches on an edge. If you could carry 250 pounds on your back, you might walk away with a little over \$75,000 worth of gold, which would make a cube a trifle larger than 7 inches on an edge. If you owned a 9-inch cube of pure gold, you would have over \$150,000.

In more than three and one half centuries, from the discovery of America to about 1850, only 151 million ounces of gold had been produced in the entire world; but in the next 82 years, ending with 1932, 959 million ounces, or 6¼ times as much, was produced at a rate 28 times as fast. The earlier production came from placer mines or from gold mines that could not be worked far below the surface. Now the amount from placers is small in comparison with that from veins; vein-mines sometimes extend a mile and a half into the earth, this having been made possible by recent technologic advances in the art of mining; the story of the winning of gold is not yet finished.

You might not know that the greatest gold mine in the United States is in South Dakota; it is called the Homestake. Alaska contains the second largest. You would rightly guess that more gold has come from California than any other state. Canada produces more gold than we do; in fact, last year the Province of Ontario alone was the source of more gold than the whole of the United States. The greatest producer in Canada is the Lake Shore mine; the Hollinger stands second. About half of the gold won annually in all the world comes from the Union of South Africa; nearly two hundred and forty million dollars' worth was won there last year. The greatest African mine is called Government Gold, with the Crown mine a close second. Either produces nearly three times as much as our largest mine.

Truly it may be said that there is a golden thread running through the embroidered tapestry of history, from dim prehistoric figures of men trading nuggets, to our own financiers and leaders of industry conducting vast transactions based upon minted gold, but it should not be overlooked that this filament of gold is interwoven throughout with one of silver, and that silver is now employed as the basis of money by Eastern peoples as numerous as those of the West who use gold for the same purpose.

# THE WORK OF THE BUREAU OF STANDARDS IN LIGHT AND HEAT

By Dr. CLARENCE A. SKINNER
PHYSICIST, THE NATIONAL BUREAU OF STANDARDS

THE Bureau's activity in light includes: The wave-length measurement and classification of emission and absorption spectra, along with certain extreme phases of chemical analysis for which these are especially applicable; investigation and tests involving measurements of polarized light and its applications, especially in the testing and technology of the sugars; development of methods and measurement of factors which determine color, measurement of the spectral transmissive and reflective properties of materials and the color grading of light sources and materials; development of methods and testing the performance of optical instruments, development of instruments for new types of service and measurement of refractive indices of optical materials; the development and maintenance of basic and working standards of light and photometric testing of illuminants; development of radiometric methods and instruments, development and maintenance of standards of thermal radiation; investigation and sensitometry of photographic emulsions and development of photographic methods; standardization of equipment for producing, controlling and measuring x-radiation, development of methods and measuring the radium content of materials; the application of the interferometer to the accurate measurement of length, including the calibration of end standards and ruling of line scales with light wave-lengths as the working standards.

It is interesting that light furnishes the longest and shortest units of length. The light-year, about 250 million times the earth's equatorial circumference, is used for designating the distance of stars; but the accuracy of this unit, equal to that of the measured velocity of light, is not important. On the other hand, the wave-length of the red radiation of cadmium, so short that 100 of them make up a length doubtfully detectable by the unaided eye, is prized for its accuracy, reproducibility, constancy, the facility with which it can be magnified for observation purposes and the range of its application.

The Bureau has contributed extensively to the development and adoption of interference methods in metrology, and has shown through these that precision gage materials are commonly subject to change of length with time. Crystal quartz even does not keep its length accurately in step with its temperature when carried through a moderate temperature cycle of 30° C. Fused quartz (silica glass), on the other hand, with its extremely low thermal expansivity, appears to be ideal material for such purposes. The Bureau has several decimeter end gages of this material now in the final stages of preparation, for calibration by light wave-lengths. By the use of these gages in the different national laboratories, it is hoped to ensure international length standardization to an accuracy of one part in a million. Also, using light waves to step off the intervals, line scales ranging in length from a millimeter to a meter are ruled. These serve as exact master scales in precision establishments where the elimination of the customary correction chart improves greatly both the speed and accuracy of production.

For working standards of length sev-

THE BUREAU'S SELF-CHECKING SET OF OPTICAL PLANES OF FUSED QUARTZ

THE DISKS ARE APPROXIMATELY 11 INCHES IN DIAMETER AND DEVIATE LESS THAN ONE HUNDREDTH OF A WAVE-LENGTH FROM A PERFECT PLANE. THEY ARE THE BUREAU'S BASIC STANDARDS FOR TESTING BOTH THE PLANENESS OR CURVATURE OF SURFACES AND THE PERFECTION OF "STRAIGHT EDGES."

eral hundred wave-lengths of the iron spectrum distributed from 2500 Ångstroms in the ultra-violet to 8500Å in the infra-red have been measured at the Bureau to one part in 2 million or better. These have been adopted as secondary wave-length standards by the International Astronomical Union. A search is now in progress for other wave-lengths, accurate to one part in 20 million or better, which may serve along with the cadmium wave-length as basic standards.

In photometry, the recognized unsatisfactoriness of flame standards led the Bureau several years ago to set up working standards of carbon filament incandescent lamps, rated in candle-power. Extensive comparisons have revealed these to be highly satisfactory, lacking neither in constancy nor durability. They permit photometric measurements accurate to ¼ per cent.; where, using flame standards, certification closer than 2 per cent. can not be obtained. Spectrophotometrically standardized optical filters used in conjunction with these incandescent carbon filament standards permit, by eliminating color differences, the accurate candle-power measurement of present-day illuminants.

A primary standard of light, a source accurately reproducible from specification and reasonably near the color of the incandescent carbon filament secondary standards, has been realized at the Bureau relatively recently, in the form of a black body radiator at the temperature of freezing platinum; and its candle-power has been measured.

For the past 20 years the Bureau has also been using and issuing carbon filament lamps as working standards of total radiation, calibrated with the black body radiator as primary standard. These have proved constant over a period of several years and of wholly negligible deterioration with use.

The problem of standards of color is much more complex than that of radiant or luminous power. For example, the color of things, which are not themselves sources of light, depends on the illumination used so that a specification of their color must include a specification of the illuminant. The physical counterpart of, or stimulus evoking color, is in general a mixture of light of different wave-lengths or spectral distribution. The same spectral distribution always evokes the same color sensation, though the same color sensation can be produced by different spectral distributions. Where reproduction of a given color is to be attained through reproduction of the spectral distribution, a spectrophotometric analysis is made. The standardization of railway signal glasses, in which the Bureau is at present engaged, is an important example of this type of color measurement. The Bureau makes also such spectrophotometric tests for the public and issues spectrophotometrically calibrated sets of colored filters, by

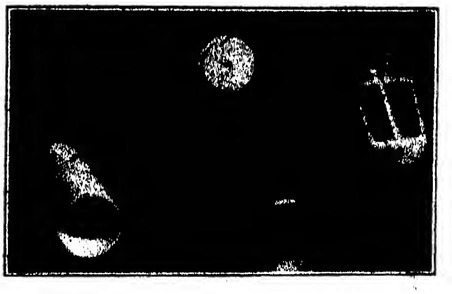
means of which an individual laboratory may check the accuracy of its own spectrophotometer.

For the reproduction of a given color, irrespective of its spectral composition, the Bureau has under way the standardization of a set of 400 colored glasses, which, singly or in combination, will match four fifths of the estimated million different practicable colors—the nearly pure spectral colors not being reproducible by this set. Over one hundred of these glasses, representing colors used in the edible oils industry, have been standardized and graded; and samples, nominally the equivalent of any in this group, are accepted for standardizing.

Relative to the color of illuminants, of which the most important range from the candle to the sun, the Bureau is now preparing to standardize these in terms of the temperature of a black body radiator, "color temperature," which most nearly matches the color of the given source. In this connection, it has also developed a series of optical filters for converting lights of lower color temperatures to various higher color temperatures; and one of these combinations has been adopted as an international standard for photographic sensitometry.

The list of measuring instruments and devices developed in this field by the Bureau includes: Polarimeters, colorimeters, special types of photometer, radiometers, a photographic sensitometer, an optical coincidence gage, optical components for special types of service and interferometers of varied application—the most recent being an instrument for measuring the tilt of the earth's strata which serves as a warning of approaching earthquakes.

In heat one of the important functions is the maintenance and distribution of the temperature scale. The thermodynamic scale, being independent of the properties of any particular material, is an ideal temperature scale; but precise measurement on this has proven to be solely a research laboratory project. For practical purposes, the adoption of secondary scales has been imperative. As a basis for such, the Bureau has used mercury-in-glass and platinum-resistance thermometers, rare metal thermocouples and optical pyrometers—these having the attendant advantages of speed, high degree of precision and reproducibility. Being to some extent arbitrary, however, both as to specifications for calibrating secondary thermometers and as to temperature ranges for which the different types were used, minor differences between laboratories were inevitable. To eliminate them, the Bureau took an active part in negotiations which led in 1927 to the adoption of an international temperature scale by the General Conference of Weights and Measures, representing 31 nations. The international scale is based on six fixed points and precisely defined methods of interpolation between them and extrapolation above the highest. For the interval 0° to 660° C. the platinum resistance thermometer is standard, and the same with a different calibration covers 0° to −190° C.; for 600° to 1063°, the thermocouple of platinum against 90



PLATINUM INGOT, B, AND REFRACTORY PARTS, A, C, D

USED BY THE BUREAU OF STANDARDS IN A RESEARCH TO OBTAIN A SOURCE OF LIGHT SUFFICIENTLY REPRODUCIBLE TO SERVE AS A FUNDAMENTAL PHOTOMETRIC REFERENCE STANDARD. THE BUREAU'S METHOD HAS BEEN PROPOSED FOR INTERNATIONAL ADOPTION AS A PRIMARY STANDARD OF LIGHT.

platinum-10 rhodium is specified. Above 1063°, the freezing-point of gold, the temperature is defined in terms of monochromatic radiation from a black body—without specifying any particular instrument, but theoretically identical with the thermodynamic scale.

Bureau contributions to the development of the methods and instruments, which form the basis of the international scale, are the investigation of the boiling-point of sulphur and freezing-point of silver; the design and construction of resistance thermometers, which have found extensive use; the improvement of methods of preparing platinum and its alloys in a state of purity and the production of thermocouples for testing this purity; and also the development of an optical pyrometer, including technique for precise measurement.

Work in gas thermometry at the Bureau is designed to provide, first, a working scale of temperature below −190° C., the present limit of the standard scale; and second, further basic data in the range now covered by the international scale.

To make an exact temperature scale available, the Bureau tests liquid-in-glass thermometers of numerous types at temperatures ranging from −190° to 500° C.; also resistance thermometers, thermocouples, optical and radiation pyrometers to an accuracy demanded for the most precise laboratory instruments. Through the development of special methods and apparatus more than 100,000 clinical thermometers also are tested annually.

Investigations on the temperatures of fixed points have been completed on the freezing-points of palladium, platinum and iridium; and that of rhodium is now under way. To attain the accuracy of 1° or better at the lower temperatures and that of but few degrees at the higher, it was necessary in these investigations to prepare material of extraordinary purity and to provide containers in which it could be melted without contamination. For this latter purpose, thorium oxide, fused by a special technique and molded into crucibles, was used. A necessary additional factor contributing to the successful determination of the freezing-points of metals has been a high frequency induction furnace. In the region of very low temperatures, liquid hydrogen and more recently liquid helium have been used in attaining temperatures below that of liquid air. By fractional distillation of liquid hydrogen, a residue was obtained in which the hydrogen isotope of mass 2 was discovered spectroscopically at Columbia University. Apparatus and methods have recently been developed, in cooperation with the fixed nitrogen research laboratory, for measuring specific heats from the temperature of boiling hydrogen to ordinary temperatures. In the range of liquid helium temperatures, an extensive investigation on superconductivity, especially as affected by the frequency of the current, has been carried on.

In calorimetry, where accurate temperature measurements are of first importance, the Bureau makes available standard heats of combustion in the form of standard samples (pure benzoic acid, naphthalene and sucrose), by means of which the user of a bomb calorimeter may make an accurate calibration of his instrument without a difficult and elaborate primary calibration. Considerable attention has also been given to the more precise definition of heats of combustion, involving the establishment of standard states, and the reduction of results to the basis of these standard states. Investigations of methods of gas calorimetry completed 20 years ago have formed the basis for methods of testing heating value of gas supplies, both by gas companies and regulatory bodies.

The most extensive work in calorimetry carried on by the Bureau has con-

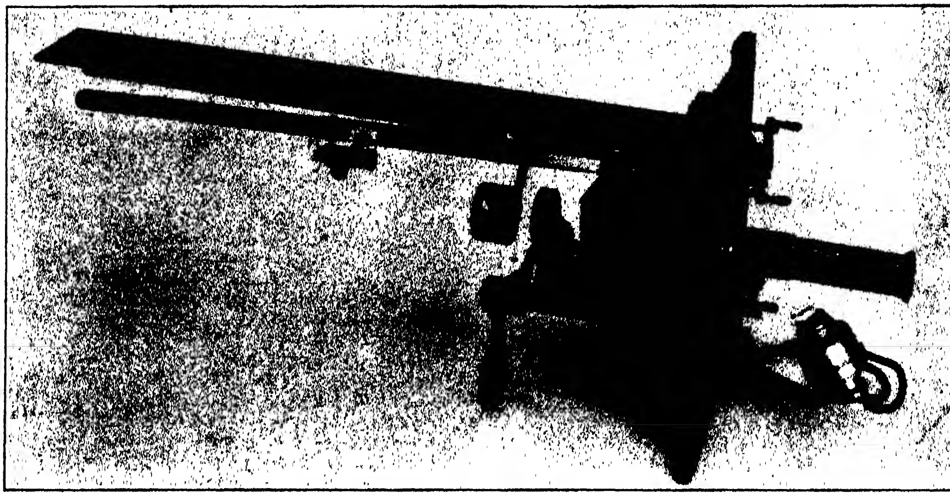
GENERAL VIEW OF LABORATORY EQUIPMENT

DEVELOPED BY THE BUREAU OF STANDARDS FOR MEASURING THE THERMAL PROPERTIES OF SATURATED STEAM. IN THE FOREGROUND IS SEEN THE CALORIMETER DESIGNED FOR OPERATION AT TEMPERATURES UP TO 700° F. (375° C.) AND STEAM PRESSURES UP TO 3,200 POUNDS PER SQUARE INCH. THE PURPOSE OF THE RESEARCH IS TO OBTAIN RELIABLE FUNDAMENTAL DATA ON THE BEHAVIOR OF STEAM FOR THE FORMULATION OF WORKING TABLES.

sisted in determining the thermodynamic properties of materials, such as steam and refrigerating media. This involves the preparation of material of high purity, determination of such properties as the pressure-temperature relation for the saturated vapor, the heat content of the liquid, the latent heat of vaporization, the pressure-temperature-volume relations for the superheated vapor and the specific heat of this vapor. Complete working tables are prepared from these data for the use of engineers in the design and testing of power plant equipment; thus, tables of the properties of ammonia have been issued and have become the standard of the refrigerating industry, both at home and abroad.

Similar work on the properties of steam forms part of an international program designed to provide more reliable data and to cover adequately the higher range of temperatures. The Bureau's measurements, which were preceded by a careful study of the theoretical basis in designing the apparatus, have been completed up to 270° C. (518° F. and 800 lbs./sq. in.). Work above this range is now in progress. Two international conferences, in 1929 and 1931, used the Bureau's results in establishing skeleton tables covering existing knowledge of the properties of steam.

A contribution to the classical problem of determining the mechanical



COBLENTZ THERMOPILE FOR MEASURING RADIATION FROM THE STARS

It was with this instrument that the first successful measurement of heat from stars was made in 1914 at Lowell Observatory. It was later used in a survey of the temperatures of the polar caps, bright and dark areas and clouds of the planet Mars.

equivalent of heat consists in pointing out that its importance is entirely artificial. Heat is a form of energy and can therefore be measured and expressed in the usual energy units, such as ergs or joules, so that there is no necessity for an independent energy unit, such as the calorie. When this is recognized, the problem of determining the specific heat of water does not differ essentially from the problem of determining the specific heats of other substances.

In the subject of heat transfer, extensive investigations of the thermal conductivity of insulating and building materials and of heat transfer through building walls have provided data from which the insulating value of a wall of specified construction may be calculated; as verified by measurements on representative types of walls. In addition, the conductivities of metals and insulators at high temperatures are being measured. By means of an interferometer and using the refractivity of air as a means of indicating its temperature, it was possible to determine the temperature gradients in the air surrounding a heated body and thus to make a detailed analysis of the manner in which heat was transferred from the heated body to the air.

Another series of investigations has been concerned with the reduction of fire losses in buildings, by testing fire protective materials and construction, in furnaces designed to maintain temperature conditions corresponding to severe fires. The results are expressed in terms of the period of fire exposure during which satisfactory endurance is to be obtained. To make them applicable to existing conditions, the intensity and duration of fires occurring in various classes of building occupancies have been determined by burning experimental buildings and comparing the results with furnace tests. Numerous tests on the types of walls most commonly used have thus made it possible to assign appropriate fire resistance periods to the several types. Similar tests on floors are under way.

As fire is a hazard to life as well as

to property, attention has been given such matters as the provision of adequate exits from buildings, and the protection of audiences by suitable stage curtains. The safe storage of records, the fire protection of government property, the treatment of fabrics and other combustible materials to reduce flammability, means of eliminating causes of fires and related problems have all received attention.

In the subject of power, where the thermal energy from the combustion of fuels is converted into mechanical energy, the Bureau's activity has been centered on the automotive type of engine, the fuels and lubricants required in its use and the vehicles propelled by it. In 1917, the new altitude laboratory, designed for testing aircraft engines under upper air temperature and pressure conditions, signally justified itself by showing that the proposed specifications for aviation gasoline were unnecessarily severe; thereby relieving the country at a critical time of having a condition imposed which would have taxed its resources to the utmost. This laboratory is particularly fitted for studying the effect of: pressure, temperature and humidity of the air, cylinder temperature and oil viscosity on the behavior of aircraft engines.

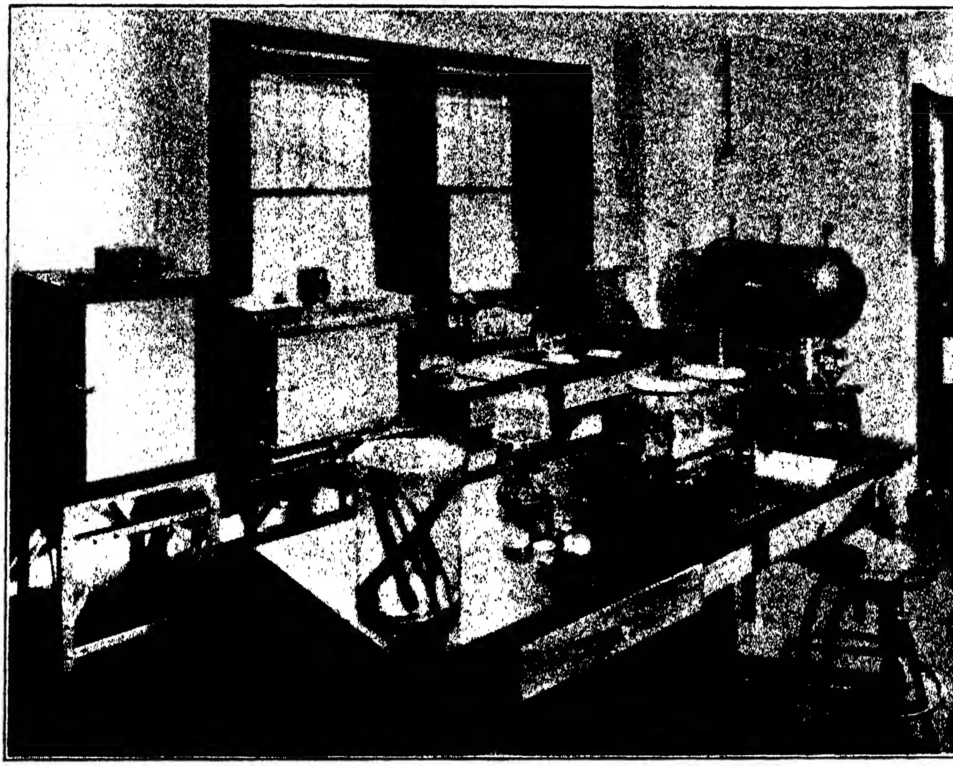
In 1922, the National Automobile Chamber of Commerce, The American Petroleum Institute and the Bureau entered into a cooperative agreement for the purpose of coordinating the efforts of both the automobile and the petroleum industry to the end that engines might be adapted to use the fuels available and that fuels most suitable for use in engines might be marketed. In this connection, a wide variety of problems, the nature of which has constantly changed with conditions in the industry, has been taken up. When gasoline production was barely sufficient, the problem was to obtain the greatest number of miles per barrel of crude. With the increase in production of crude oil beyond requirements, and cracking processes augmented the supply of gasoline obtainable, increase in mileage has taken a place second to that of increase in satisfaction of operation. For example, the volatility of gasoline should be such as to afford easy starting, yet not lead to boiling in the fuel lines, resulting in vapor lock. Specifications for such a gasoline have been formulated as the result of extensive tests. The knocking tendency of fuels has also been studied and means have been developed for making consistent knock ratings of fuels tested in different laboratories.

# THE PROGRESS OF SCIENCE

## THE MORRIS ARBORETUM OF THE UNIVERSITY OF PENNSYLVANIA

One of the most munificent gifts to the cause of university education in America was made in the will of the late Miss Lydia Thompson Morris, in which she provided that her home in Chestnut Hill, Philadelphia, and her adjacent farming property in Montgomery County should become The Morris Arboretum of the University of Pennsylvania. The home property, "Compton," has long been famous for the beauty of the location and for the very remarkable collection of trees and shrubs planted there chiefly by her deceased brother, Mr. John T. Morris. These plantings occupy more or less completely about 50 acres and are especially rich in specimens from eastern Asia. Miss Morris' will indicated the purpose to which she dedicated this splendid property. The arboretum shall be maintained as a primary object, and the extensions that were being carried out by her are to be continued. The will also provided that a school of graduate botanical research shall be organized and conducted. To aid this purpose, the granting of fellowships is authorized, also the establishment of scholarships for boys and girls studying horticulture and other botanical subjects. The hiring of noted scholars to give lectures, the publication of popular and scientific works, the supporting of botanical researches in this and in foreign lands, the growing of plants for distribution to the interested

THE WALL GARDEN AND THE MANSION



LABORATORY FOR INVESTIGATION OF TREE DISEASES

public and the construction of suitable buildings are among the objects mentioned.

The management and direction of the arboretum is to be conducted through the department of botany of the university. It is directed that the funds of the estate not otherwise provided for should be available for the support of the arboretum and of the projects undertaken by it.

The university became responsible for the initiation of this program last October, and considerable development has taken place. Several hundred new trees and shrubs have been received and placed in the nursery.

The labeling of the plants now in the arboretum has been well advanced, although much critical work still remains to be done. A herbarium record of the plants now present is well begun, representing the plants in bloom, in fruit in many cases, and in winter condition. This herbarium will receive representations from new plants introduced and will offer a wealth of material for the critical botanist.

The arboretum, by participation in the support of Rock's recent expedition on the China-Tibet frontiers, has already received hundreds of kinds of seeds collected by that explorer, among them over 150 Primulas, many of them already germinating in the arboretum greenhouses. Seeds of over 500 collections of Rhododendron are now here.

The buildings at the arboretum are being actively employed. Residences for the superintendent, for the head gardener and for watchmen in different parts of the total area of 160 acres extending along the eastern side of the Wissahickon Creek are in use. The family residence contains an excellently equipped laboratory for the study of diseases of woody plants, in which half a dozen graduate students are at work

ONE OF THE JAPANESE GARDENS

under the direction of Professor Harlan H. York, of the botanical laboratory of the university. Laboratory work is in active operation on problems of mineral plant nutrition by two graduate students. One graduate student working in the mineral constituents of the soil is studying under Associate Professor Edgar T. Wherry. Associate Professor Conway Zirkle is conducting studies in the Bloomfield section on plant genetics. Assistant Professor John Milton Fogg, Jr., is in charge of taxonomic studies on the pines and oaks of the arboretum being carried on by two investigators.

The attic of the garage building has been equipped with an Allison magneto-optical apparatus, which two graduate students are using in studies on the absorption and exchange of mineral constituents of plants under the general direction of Professor True.

Mr. James Lambert, superintendent of the botanic garden of the university, is superintendent of the arboretum, where he is now in residence.

Professor Rodney H. True, of the department of botany and director of the botanic garden of the university, has been appointed director of the arboretum with part-time residence there.

An advisory staff, with members from the school of fine arts, the departments of zoology, chemistry and engineering, has been approved.

Thus, the magnificent gift of Miss Morris opens the door of opportunity for plant studies at the university on a wide basis with financial support to give effect to the program, and promises to make this university and Philadelphia one of the great botanical centers of the country. Should it continue to prosper, it may in time rank with the Royal Gardens of Kew, the Jardin des Plantes in Paris, and the Arnold Arboretum, of Boston, in the world of plant study.

RODNEY H. TRUE

## THE HIGH POTENTIAL STATION AT NEW BEDFORD

Ten million volts will soon be available to a group of Massachusetts Institute of Technology physicists. In an airship hangar on Colonel E. H. R. Green's estate at Round Hill, the largest building they could borrow for their experiments, a gigantic electrical machine is being groomed for the study of the effects of high voltages. It consists of two columns surmounted by fifteen-foot hollow aluminum spheres. Men can climb into these hollow metal balls and their interiors will serve as laboratories where the effects of high voltage electricity upon matter can be observed.

The giant electrical machine will provide the world's highest potentials of electricity under human control. Lightning has higher voltage, but man can not effectively harness the lightning.

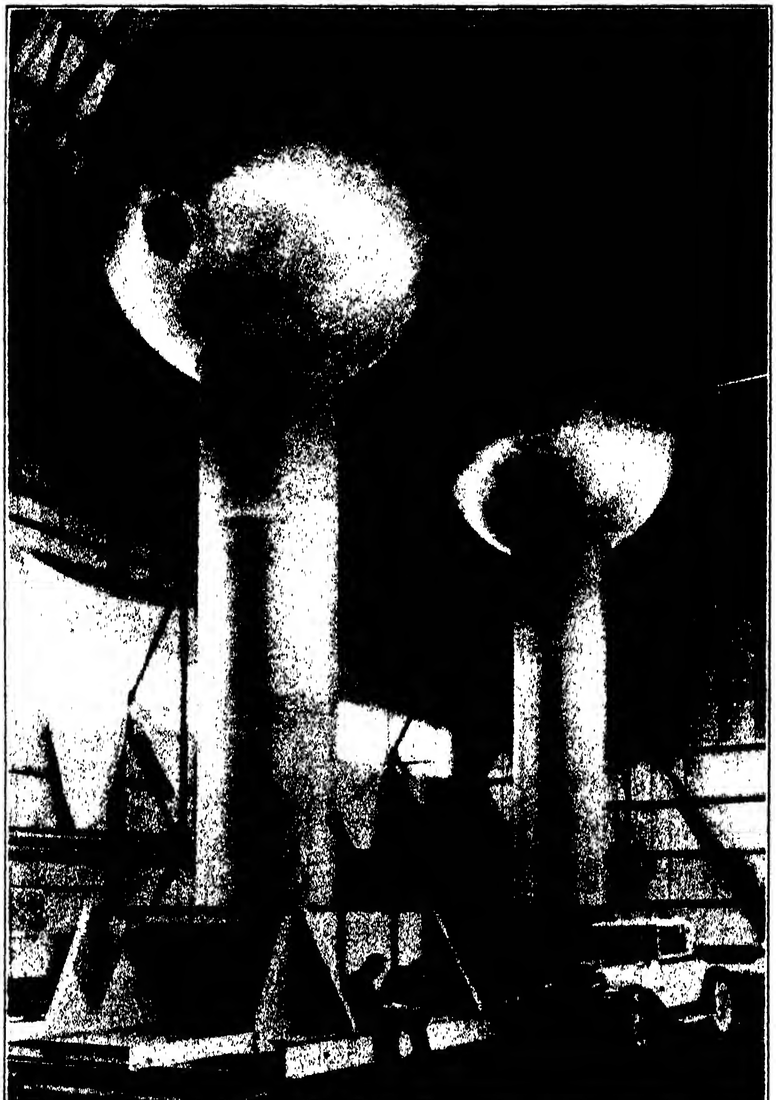
One surprising thing about this ten million volt generator is that it needs no electrical input. It is its own power house. No large transformers are needed. One of the oldest methods of generating electricity is used in this newest high voltage machine. Benjamin Franklin experimented with static machines, and that other great American pioneer in physics, Joseph Henry, used generators of frictional electricity to shock his students who held hands in a circle.

Stroke a cat or comb your hair on a dry day and see the sparks fly. This method of generating static electricity is essentially the same as that in the ten million volt static machine about to be tested in New England. Static electricity antedates the electromagnetic method that is used in the generation of practically all the electric power to-day. The Greeks knew that by rubbing a piece of amber with a cloth an electric charge could be generated. With the practical application of the discoveries of Faraday and Henry, that motion in a magnetic field can generate a current, with the development of the vast electrical industry based upon these principles, static electricity did not have the opportunity of becoming practically useful but remained within the laboratory in the bags of scientific tricks of physics professors.

A modest young man, just thirty-two, is responsible for the application of the principles of static electricity in the development of the electrical machine which will soon give science useful potentials of many millions of volts. Dr. R. J. Van de Graaff was a Rhodes scholar in Oxford when it first occurred to him to use static electricity to obtain high voltage. While in England he did not have the opportunity to make the necessary experiments, but after leaving Oxford he went to Princeton University as a National Research Council fellow. There, with the cooperation of Dr. Karl T. Compton, then professor of physics at Princeton and now president of the Massachusetts Institute of Technology, Dr. Van de Graaff made the first Van de Graaff generator. It cost less than a hundred dollars and it exceeded in voltage developed all the other devices upon which physicists had been working diligently in a half dozen other laboratories.

So striking was the success of the 1,500,000 volt model that Research Corporation funds were obtained under the auspices of the Massachusetts Institute of Technology to build the ten million volt machine which is now about to go into the service of physics.

In principle the Van de Graaff generator is simple. From near the surface of the ground to the elevated hollow cylinders there run moving belts. Electricity is picked up upon these belts at the ground level and it is then conveyed, like water in a bucket pump, to the hollow spheres where it is dumped into them and travels to their surfaces. It is not even necessary to provide a source of low voltage electricity to spray upon the belts as the belts can create and pick up the necessary electricity without aid. One of the hollow cylinders thus has its



THE HIGH POTENTIAL APPARATUS IN THE AIRSHIP HANGAR

surface charged positively and the other is charged with negative electricity. How much electricity the hollow cylinders will hold without spilling over, or sparking like artificial lightning, one from the other, depends upon their size and the atmospheric conditions.

A relatively large amount of electricity, a thousand kilowatts, will be generated by the ten million volt machine when it operates. This is as much as the power plant of a small town generates. Actually the current amounts to 100 milliamperes at a potential of ten million volts.

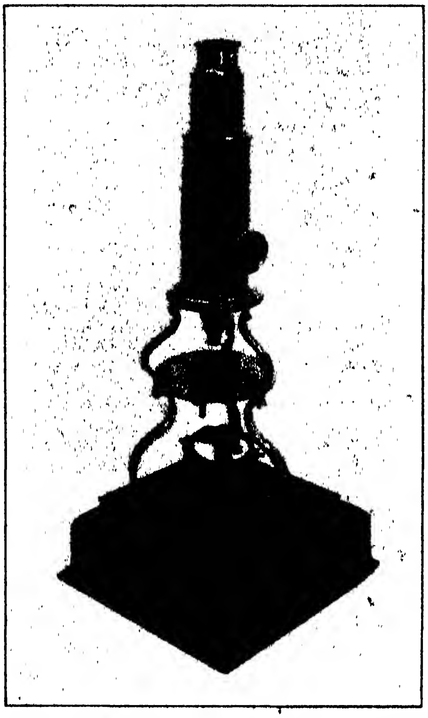
The generator would light 90,000 ordinary 10 watt, 110 volt incandescent electric lamps, if connected in series, and there would be 10 per cent. current margin to spare. If these lamps were set as close together as possible, say eight to the foot, they would string out to about two miles.

WATSON DAVIS,
*Science Service*

## HISTORICAL MICROSCOPES AT THE NEW YORK BOTANICAL GARDEN

HISTORICAL microscopes assembled in what is believed to be the largest collection of its kind in the United States have lately been put on exhibit at the New York Botanical Garden.

Dating from 1740 to the latter part of the nineteenth century, these instruments reveal the progress made from the early, crude, compound microscopes to the nearly perfected achromatic lenses of a century and a half later.

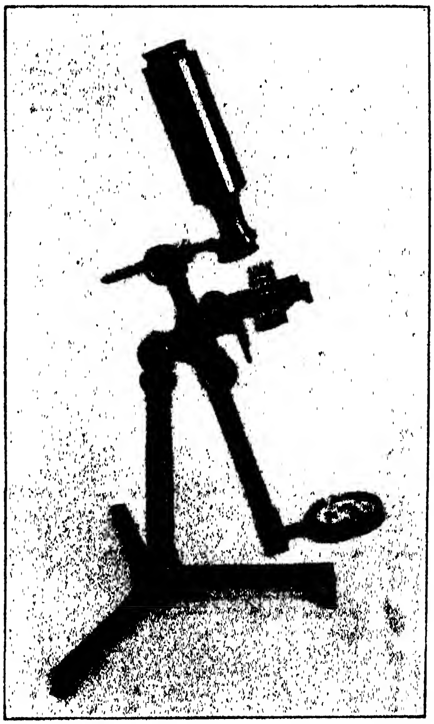


ONE OF THE EARLIEST MICROSCOPES IN THE NEW YORK BOTANICAL GARDEN'S COLLECTION, BUILT BY CULPEPPER IN 1740–45.

Despite the imperfections of the earlier models, it was with instruments such as these that the first of the modern botanists—de Jussieu, his nephew Lamont, Linnaeus and later Lamarck—made their studies and discoveries which revolutionized the concept of their subject. Though they used compound microscopes whenever necessary, their vision was continually blurred by the presence of color bands resulting from refracted light rays passing through the lenses. It was many years before achromatism was successfully accomplished. As late as 1821, it was believed impossible to construct a good achromatic microscope, and the single lens was then recommended as the only practical type.

Amici of Florence, one of whose instruments is in the New York Botanical Garden's collection, tried to correct chromatic aberration by a right-angled prism placed immediately above the objective, designed to deflect the light rays through the body-tube.

But this was not wholly successful. A few years later, in 1829, Jackson

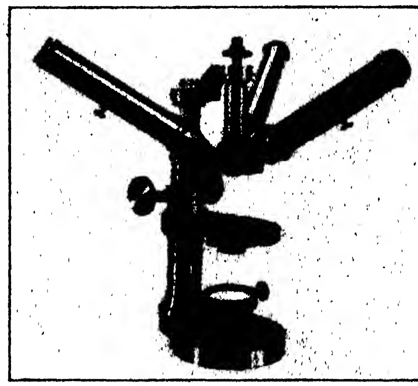


W. & S. JONES OF LONDON MADE THIS MICROSCOPE, WHICH THEY DESCRIBED AS THEIR "MOST IMPROVED COMPOUND MICROSCOPE," ABOUT 1797. IT HAS A REVOLVING DISC OF SIX MAGNIFIERS, FOUR OBJECTIVES, AND A LARGE NUMBER OF ACCESSORIES.

Lister cemented a plano-concave and a convex lens together with Canada balsam, which is transparent, and thus diminished one half the loss of light from reflection and made the field clearer and brighter. Other improvements fast followed, completely changing the character of the instrument in a subsequent ten-year period. The most important developments in the whole history of the microscope were made during the middle of the nineteenth century. "Little room for improvement can be considered to remain," said one writer at this time.

The microscopes of this changing period, of which there are a number in the botanical garden's collection, were provided with innumerable accessories, including a boxful of prepared slides, showing insects' wings, minute plants and animals, sections of leaves, pollen, microscopic eggs and such objects of fascination for the aided eye. But more important, more exciting, even, to the layman who peered through the tube as a means of entertainment, was the use of the fish-pan, which was part of the equipment. This was a shallow, oblong dish, fitted with clamps or provided with stout twine to hold a small live fish or frog in place. Through the microscope then the wonders of circulating blood could be observed in the fish's tail or the webs of the frog's feet.

"The fact that this collection of microscopes is so rich in the earlier models, which are increasingly difficult to obtain, is an appropriate reason why it should be made a still more comprehensive group," Robert Hagelstein, honorary curator at the New York Botani-



THREE PEOPLE CAN VIEW THE SAME OBJECT AT THE SAME TIME THROUGH THIS MICROSCOPE, MADE BY NACHET ET FILS, PARIS, SHORTLY AFTER THE MIDDLE OF THE NINETEENTH CENTURY.

cal Garden, said in issuing a plea for the contribution of additional instruments. The basis of the collection is a gift of twenty microscopes made some years ago by the late Charles F. Cox, when a member of the board of managers.

C. H. W.

## SUMMARY OF THE PRESENT POSITION OF OUR KNOWLEDGE OF ANTERIOR PITUITARY FUNCTION

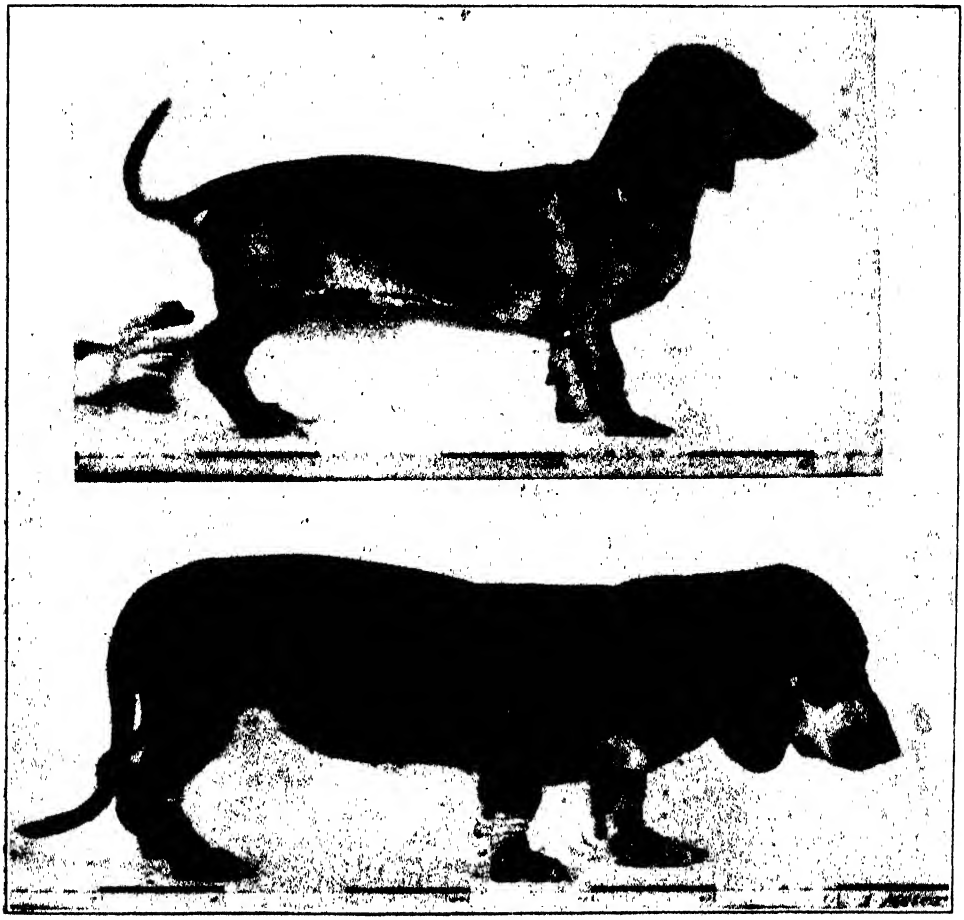
It is possible that we are at the threshold of a new era in the field of experimental medicine. Dr. Herbert M. Evans, director of the institute of experimental biology at the University of California, who has recently completed a year's work at the Rockefeller Institute for Medical Research, believes that the investigation of the ductless (endocrine) glands probably will yield methods of prevention and control of disease comparable to those developed in the "bacterial epoch" inaugurated by Koch and Pasteur. This subject of endocrinology suffered at its birth from the extravagant assertions of those who claimed to have found in the endocrine glands the long-sought "fountain of youth," or who saw in endocrinology a tool for the lucrative profession of making fat ladies thin. Even so, the investigation of ductless glands has already yielded the greatest single achievement of present-day medicine—the discovery and isolation of insulin.

The hypophysis, or pituitary body, is

a small gland lying at the base of the brain almost in the mathematical center of the head. The Roumanian surgeon, Paubsco, observing that his animals died soon after the removal of the pituitary, concluded the gland was essential for life. This view was held until Harvey Cushing skilfully demonstrated that when the pituitary is removed *without injury to other brain parts*, death need not supervene.

Though the hypophysis was thus shown not essential for continuance of life, it can be demonstrated that complete excision of the gland is followed by progressively more serious ill effects in the body. The triumph of surgery in successfully removing the pituitary without brain injury opened opportunities for test in replacement therapy. By the use of animals deprived of the pituitary we can test gland extracts and determine if we have secured all essential principles of the gland. What are the entities furnished by the pituitary which play so important a rôle in the physiological economy of the animal and which cease to function on complete removal of the gland?

Removal of the pituitary in adult animals first shows little change within the body except for genital retrogression,



EFFECT OF GROWTH HORMONE

CHANGES PRODUCED IN DACHSHUND BY DAILY ADMINISTRATION OF ANTERIOR HYPOPHYSEAL GROWTH HORMONE FOR A PERIOD OF EIGHT MONTHS.

but on removal of the gland or its anterior lobe in young animals there is a cessation of growth characterized by continuance of juvenile structures, such as milk dentition and persistence of epiphyseal cartilages of long bones. Bones may alter in shape, and evidences of disturbed calcium metabolism are indicated. Complete correction of such conditions will occur on injection of a growth hormone from the anterior lobe of the hypophysis into the hypophysectomized animal, in such a way that comparative potencies of growth hormone extracts may be determined and tests for purity made.

A striking effect of removal of the pituitary in the young animal is the failure of the genital system to develop, while in the adult a retrogression occurs with loss of sex interest and desire and ability to produce mature germ cells. Overdosage of pituitary extracts or implantation of the gland tissue in normal immature rats secures a complete sexual maturity.

The hypophysis elaborates a hormone-regulating mammary secretion as well as regulation of sexual maturity, and the experiments of Correr and Riddle will soon establish the fact of a hormone in the pituitary which provokes the secretion of milk.

Removal of the pituitary markedly lowers the metabolic rate of animals in a manner similar to removal of the thyroid. Indeed, the two glands seem dependent on one another in their function and structure, for the thyroid undergoes histological alterations on removal of the pituitary, and injections of anterior pituitary extracts tend to restore metabolic rate and establish normal thyroid structure.

It is found that a principle may be separated by ultrafiltration from the recognized hormones of the pituitary which regulates fat metabolism. The lack of this principle probably is the cause of fat-deposition in animals suffering from hypopituitarism.

Several endocrinologists are now seeking information on relationships between the pituitary and the pancreas. It is found that hypophysectomized animals are more sensitive to insulin, and that implantation of anterior pituitary tissue in diabetic animals will cause a rise in blood sugar content.

Degeneration of adrenal cortex after removal of the pituitary and knowledge of the vital importance of the cortex led to speculation as to whether the death of hypophysectomized animals might not be due to loss of adrenal cortical function. It has been demonstrated, however, that the decline of animals lacking their hypophysis could not be arrested by injection of adrenal cortical hormone, but could be dramatically changed to improvement on administration of anterior pituitary extract, which restores the adrenal cortex to normal also. Very little can now be said regarding a hormone of the pituitary which may aid in replacement therapy in Addison's disease, but accumulating knowledge indicates that hypertrophied fragments of the accessory adrenal tissue may take over the normal function of the adrenals if anterior pituitary tissue is implanted in the body.

One can understand the causes for skepticism with which many look upon the assertions of those who claim to recognize such a perplexing array of apparently discrete internal secretory substances or hormones furnished by the one small brain-gland, the pituitary. Nevertheless, it can be stated with assurance that sufficiently sensitive test objects have been found by means of which at least five principles—growth, gonadotropic, thyreotropic, lactogenic and diabetogenic—may be said to be known with certainty. The effects of these hormones, with perhaps the exception of those for growth, are specific, and we need wait only for more refined biochemical tools before all these substances may be obtained in pure (and preferably crystalline) form.

THE SCIENTIFIC MONTHLY

OCTOBER, 1933

# THE UNITED STATES BUREAU OF BIOLOGICAL SURVEY

By PAUL G. REDINGTON

CHIEF, THE UNITED STATES BUREAU OF BIOLOGICAL SURVEY

History and literature are replete with instances of the interest that wild life has always had for man, and many are the examples of the inspiration that the various species have given him for creative effort in art and science and in industry and social betterment. By their very nature and relationships, the fur and game species so essential to the pioneers for clothing and food have become part of our economic and social fabric, and as a natural consequence the economic and recreational importance of wild life has led to research in this domain as a function of government. In the United States so many ramifications of the subject transcend state boundaries and so many have direct relationships to human happiness and economy that the problem has become one of federal concern. Fortunately for our wild-life resources, it has been appreciated that without scientific approach to this problem a wastefulness and an ignorant persecution of some forms as pests would result in the extermination of many more species than have already been lost to the world during recent times.

## Importance of Wild-life Research

The interrelationships of the various species of wild animals to their natural environment and to man can be properly evaluated only through the application of scientific principles developed by trained biologists. In the school of experience man has learned that wild-life research is essential to the perpetuation of the harmless, interesting or valuable species, and to imposing the right degree of restraint on those that would play havoc with human endeavor if left to multiply and waste at will. Even the injurious species have exemplary traits that render them valuable to man. Thus all our native species are proper subjects for conservation in suitable environment, modifications being needed locally, as observation and study develop basic facts.

Recognizing wild life as a field for inquiry, scientists have noted and recorded facts regarding the habits of the many varieties from the time of Aristotle, who has been called the Father of Natural History. Fear that some species were in danger of extermination, including many that are interesting, valuable for food or fur or for pursuit as sport, has led within the past hundred years to cooperative efforts for their protection. Most of the societies formed for the study and protection of wild life were at first local in scope, but many were later associated into national and international organizations. One of these, founded in 1883, was the American Ornithologists' Union. Among other forms of research, this union undertook detailed studies of the migratory movements and food habits of North Ameri-

DR. CLINTON HART MERRIAM
CHIEF, 1885–1910.

can birds. Interest and recognition of the compelling necessity for continuing the work were not wanting, but funds were inadequate for conducting the investigations on a sufficiently broad scale. As a consequence, in 1885, Congress appropriated funds for the establishment of a new research unit for this purpose in the Federal Department of Agriculture. This governmental wildlife service is now the Bureau of Biological Survey. Not only ornithologists and mammalogists, but biologists in general, nature lovers, sportsmen, individually and through their organizations, and many familiar with the direct economic bearing of the work have cooperated continuously to advance the Bureau's program of research.

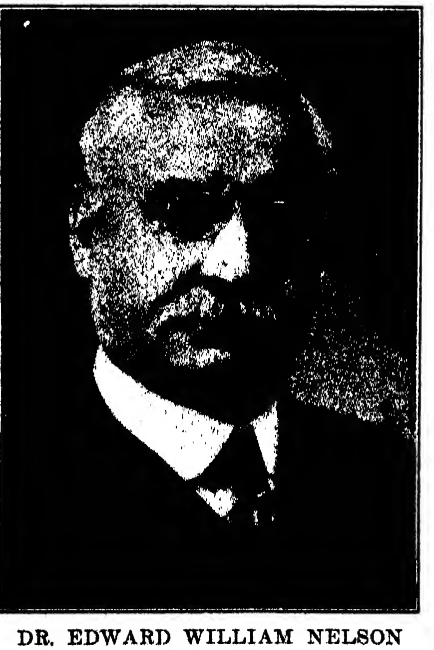
The directing personnel of the organization was influenced for more than 40 years by the interesting circumstances attending the selection of the first chief. Norman J. Colman, the Commissioner of Agriculture, had invited the American Ornithologists' Union to make recommendation for the office. At a special meeting of the council of the union in

MR. HENRY WETHERBEE HENSHAW
CHIEF, 1910–1916.

the office of Professor S. F. Baird, secretary of the Smithsonian Institution, Dr. C. Hart Merriam was nominated for the post by Henry Wetherbee Henshaw (1850–1930), who 25 years later himself succeeded to the office by promotion from the position of assistant. Henshaw directed the work until 1916, when, wishing to retire, he recommended as his successor Dr. Edward W. Nelson, who was thus advanced by Secretary David F. Houston and served until the Bureau had passed its forty-second milestone, in 1927, when he also retired, to be succeeded by the present chief.

The Department of Agriculture, said Secretary Henry A. Wallace, in a recent address to the nation by radio, "was created primarily for scientific research, its main job always has been a research job, and I hope research will always remain a principal duty." Throughout the 48 years' work of the Biological Survey strong emphasis has always been placed on the importance of scientific research by trained biologists. So long as we have any remnants of wild life within our boundaries, efficient management will be called for, as in the case of any other valuable natural resource, and to be efficient, management must have the fundamental basis of scientific research. Without research there could be no continued use and enjoyment of our native fauna, administration of protective laws, improvement in propagation of game and fur species, intelligent acquisition and maintenance of refuges for game and other birds and mammals, or dissemination of reliable information on any of these subjects.

Research conducted by the Biological Survey is concerned with the geographic distribution, migrations and classification and relationships of the various species in our fauna; with observations and studies of their food, breeding and other habits; with the nature of their diseases and the effects of these on man and his domestic animals; with the food plants and other environment essential to refuge establishment and proper utilization; and with methods of control of species that become a menace to farming, stock raising, game propagation and forestry.



DR. EDWARD WILLIAM NELSON
CHIEF, 1916–1927.

Some of these lines of research have been continued from the beginnings of the Survey, and others have been added from time to time to meet changing conditions. Studies in methods of controlling injurious species, for example, have been instituted within the past three decades; investigations having to do with fur farming and game propagation, with disease recognition and, where possible, with remedial measures, have been extended and intensified; as also has research in the protection of the game, insectivorous and other migratory birds that not only are valuable economically but serve to delight nature lovers and attract sportsmen to their haunts in proper season. All these more recent lines of study have had the benefit of fundamental research earlier undertaken.

MR. WALTER CLEAVELAND HENDERSON
ASSISTANT CHIEF, 1916–1927
ASSOCIATE CHIEF, 1927–

BEGINNINGS AND HISTORY OF THE SURVEY

Established on July 1, 1885, as a Branch of Economic Ornithology in the Division of Entomology, the organization a year later was made an independent Division of Economic Ornithology and Mammalogy; in 1896, the name was changed to Division of Biological Survey, in recognition of a form of scientific research essential to its other activities—making surveys of the major biological regions of the continent; and nine years later, in 1905, it was given its present designation of a bureau, under the administration of Secretary James Wilson.

MR. PAUL GOODWIN REDINGTON
CHIEF, 1927–

During its early history, and until the turn of the century, the work of the Survey was of a research nature almost exclusively. This period witnessed a succession of field surveys that rival in interest the work of the early explorations of our own West or the conquering of the wilds of other continents. The expeditions were conducted by field naturalists whose names are known throughout the scientific world. Their energy and resourcefulness enabled them to overcome difficulties that in no wise suffer in comparison with exploits that in other settings have formed the basis

of romantic tales of absorbing interest. Through deserts whose very names were resonant of desolation and death, through unhealthful tropical jungles, to the summits of mountains carrying perpetual snow, through unexplored mazes of northern lakes, down dangerous unmapped rivers, through untrodden mountain passes, forests and subarctic wastes, by canoe, raft, pack train and snowshoe, in sun and storm these men labored. Sometimes the exigencies of travel and subsistence alone were so great as well-nigh to exhaust their utmost resources, yet there was never a day when some new fact of distribution or habits, or some specimen of scientific value, was not added to the sum total of the Survey's achievements. And through all the years of these varied quests never a man failed to return with his precious load of notes and specimens.

The elaboration and coordination of such explorations, supplemented by more detailed studies of special areas, enabled the Survey to prepare and publish maps of the natural life zones of North America and to issue some of its more important scientific reports on the classification, distribution and habits of wild life. The details of the life zones are still being filled in from year to year, as ecological and other studies develop new facts on the horizontal and vertical distribution of the native fauna and flora and on their various community associations and interrelationships.

This early period saw also the accumulation of voluminous data on the food habits of wild birds and mammals. Those of birds were learned by field observations, supplemented by gross and microscopic examination of stomach contents and identification of the various food items by comparison with extensive reference collections of seeds, insects and other objects assembled by the Bureau and classified for the purpose. Many of the results of these investigations have been made available to the public in bulletins and circulars of the Bureau and the Department and in the numbers of the *North American Fauna,* a technical series of reports of the Survey. Magazine and newspaper articles also, and radio broadcasts, as well as books published in cooperation with local agencies and with state and national organizations, have been used to bring this information to the public.

The beginning of the present century saw increased responsibilities placed on the Bureau. Certain functions of game preservation were added with the passage of the Federal Lacey Act in 1900, and three years later the first of a steadily growing system of bird refuges was established by executive order of Theodore Roosevelt. Wild-life conservation work has been extended from time to time through passage of the Alaska game laws of 1902, 1908 and 1925, the last also covering in its provisions the protection of land fur animals in the territory; and passage of the Federal Migratory Bird Law of 1913 and its successor, the Migratory Bird Treaty Act of 1918, which was supplemented in 1929 by the Migratory Bird Conservation Act, authorizing the present system of migratory-bird refuges. The last two measures were designed to carry out the provisions of a treaty for the protection of birds that migrate between the United States and Canada, negotiated with Great Britain and proclaimed by President Wilson in 1916.

The past two decades have witnessed not only increased attention to research and enlargement of functions dealing with federal protection of migrant birds, but also entry of the Bureau into the field of cooperative control of animal enemies of agriculture, stock raising, forestry and game protection. The McSweeney-McNary Forestry Research Act, passed in 1928, enables the Survey to devote more attention to studies of the relationships between forests and wild life, many species of which are found to

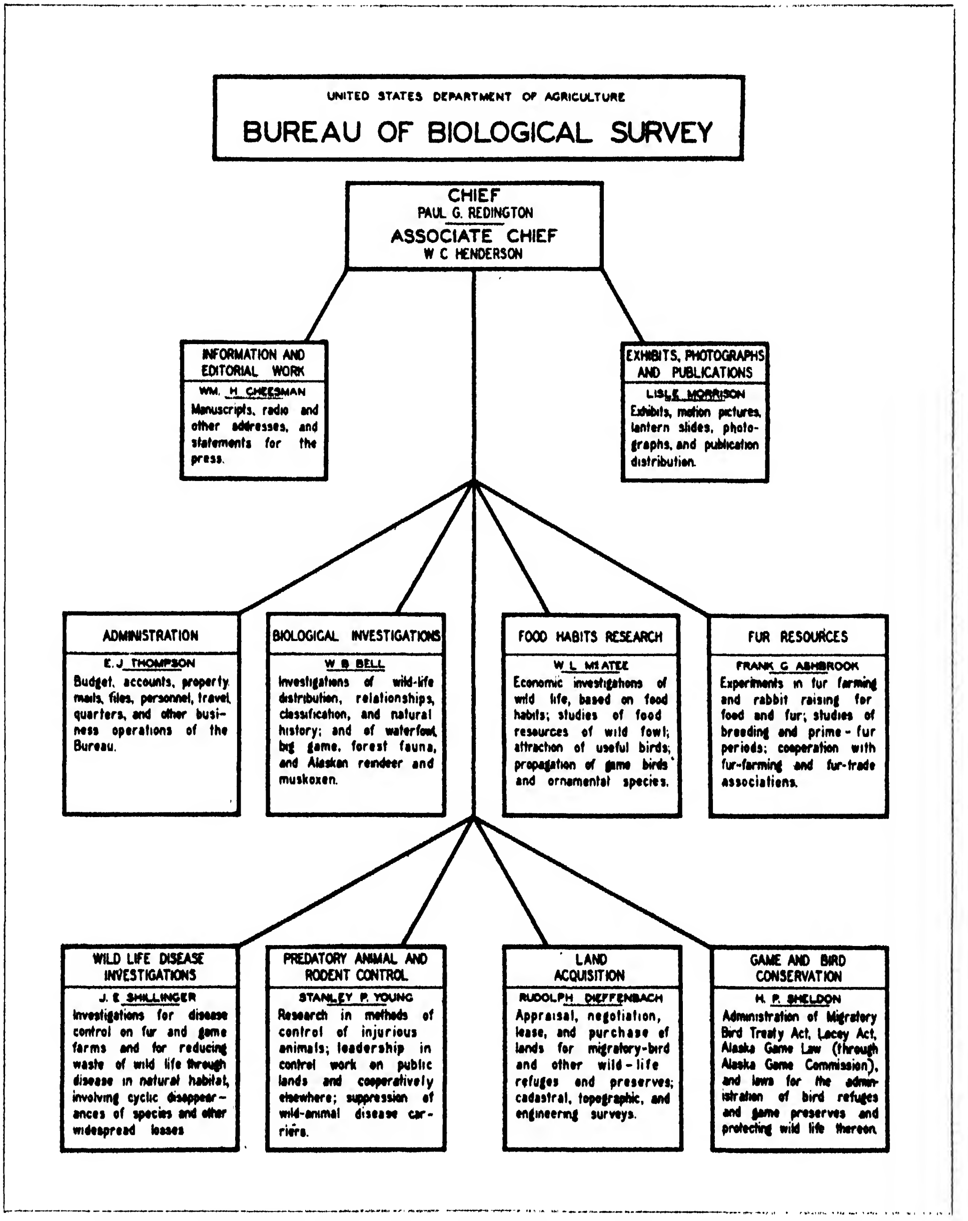



CHART OF ORGANIZATION OF THE BUREAU OF BIOLOGICAL SURVEY

have a beneficial influence on the forest, some to be important products of forested areas, and others to require some measure of local control.

In the nearly half century of the Survey's life, research has not been relinquished as the new service and regulatory duties have been added. Instead, the research begun with the inception of the Bureau has been continued on the same lines, improved by application of modern methods of approach. Furthermore, scientific study has been extended along new lines and has gone hand in hand with the assumption of new functions and duties, such as protection of

migratory birds, experiments in fur-farming, control of predators and rodents, management of upland game and selection of areas suitable for reservation as migratory-bird refuges.

### Organization of the Bureau's Research Work

As now organized, the work of the Bureau of Biological Survey in divisions and offices other than central administrative is conducted through seven divisions, five of which are engaged in research, and in four of these research is a major function. The five are as follows:

(1) The Division of Biological Investigations continues the original work of the Bureau in faunal geography and in the classification and life histories of species. To these lines of study have been added forest-fauna research in cooperation with the Forest Service; investigations for the improvement of Alaskan reindeer herds, including crossbreeding with native wild caribou; experiments in restocking Alaskan areas with transplanted musk-oxen; and new studies of water-fowl, essential to the administration of the Migratory Bird Treaty Act.

(2) The Division of Food Habits Research, continuing the original work in identification of stomach contents of birds and field study of economic ornithology, has also, through establishment of a field laboratory, intensified its research on the food habits of predatory and other mammals, as a basis for scientific pest-control operations. Other added investigations involve the encouragement of useful and control of injurious species, the investigation of food resources of migratory-bird refuge areas, the propagation of aquatic and upland game birds in captivity, and, in cooperation with associated sportsmen, the management of upland game and the increase of quail and other species on preserves.

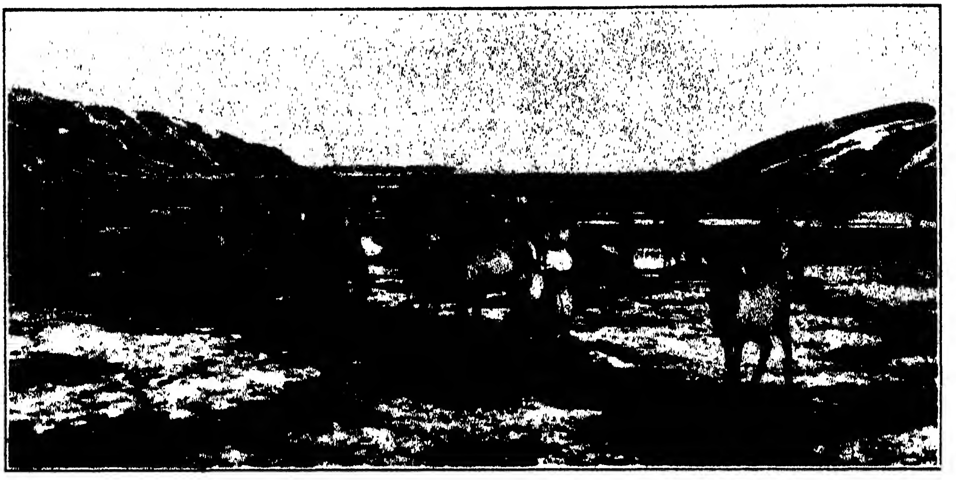
(3) The Division of Fur Resources has continued original studies of economic uses of fur animals, and now, through establishment of two field stations, conducts fur-farming experiments in the propagation of foxes, martens, minks and other valuable species, and makes investigations in rabbit raising for both food and fur.

(4) A Disease Investigations Project, under which studies are made of the maladies of water-fowl and other game birds, foxes and other wild stock on fur farms and elk and other big game, was established in 1931, to consolidate work in disease control formerly undertaken in the three foregoing research divisions.

(5) The Division of Predatory Animal and Rodent Control includes a project designated Control Methods Research, under which pharmacological and other studies are made of methods of control of injurious animals with the least menace to harmless species; and baits for use in the control of rodents of diverse feeding habits are developed and processed.

In addition to its research activities, service in predatory-animal and rodent control is rendered by the last-named division in cooperation with state and other agencies. Regulatory and related functions are performed by the remaining two of the seven divisions, as follows, all of which benefit by the basic research of the Bureau:

(6) The Division of Land Acquisition, operating under the Migratory Bird Conservation Act, is concerned with the acquisition of land and water areas as refuges for migratory birds and other forms of wild life. When areas are found by the Survey to be biologically suitable, as regards site, physical environment and food resources, this division determines ownership and market value, examines and appraises them, and negotiates to reach equitable price agreements preliminary to consideration and approval by the Federal Migratory Bird Conservation Commission of acqui-

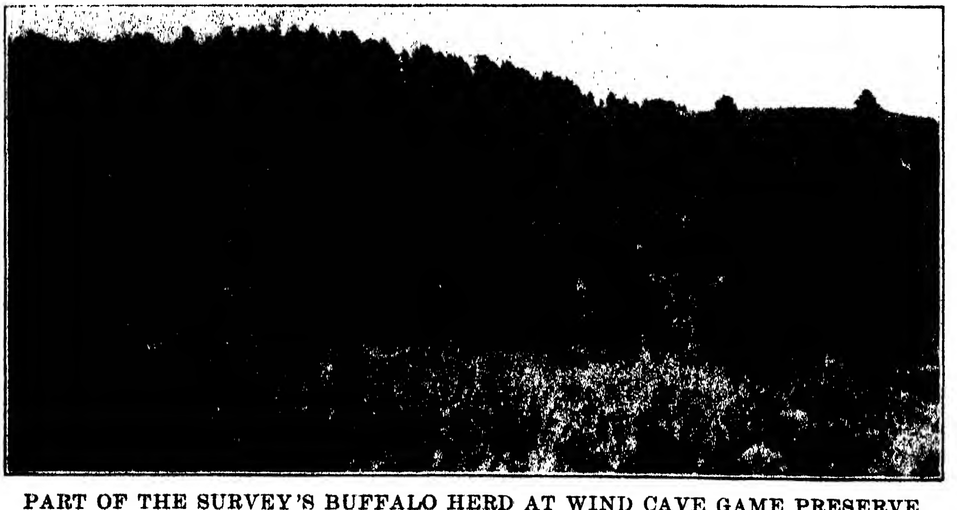


ELK FEEDING AT WINTER REFUGE OF THE SURVEY IN JACKSON HOLE, WYOMING

sitions recommended by the Bureau. Other work involves compilation of land records and cooperation in expediting payment for lands when title is obtained, and surveying areas acquired and establishing and marking their boundaries to prevent unauthorized use and trespass, with a view to adequate protection of the wild life.

(7) The Division of Game and Bird Conservation administers the Lacey Act, regulating interstate commerce in birds and mammals and importations of foreign wild species; the Migratory Bird Treaty Act, through a force of federal game protectors; laws protecting bird refuges and wild life and property thereon; and, through representation on and cooperation with the Alaska Game Commission, the Alaska Game Law. This division also administers the approximately 100 wild-life refuges now under jurisdiction of the Bureau, all of which are potential natural laboratories for wild-life research.

The work of the Biological Survey, to-



PART OF THE SURVEY'S BUFFALO HERD AT WIND CAVE GAME PRESERVE, SOUTH DAKOTA

gether with its numerous publications over nearly half a century, has been a potent factor in increasing the numbers of students of wild life. The Survey has been instrumental also in bringing wild-life conservationists and the general public more and more each year to a realization that protection of our game, fur, insectivorous and other species is of vast economic and recreational importance and involves enactment and enforcement of laws that have their foundation in scientific fact.

Extension of the protective principle to the fur-bearers, song and insectivorous species and other denizens of the wild, including also the game species for reasons other than sport, is being more and more demanded as our people become better informed regarding the economic and social values of wild-life management and the need of preserving areas of natural habitat. Better now than ever before the public understands the necessity of perpetuating the benefits that accrue to man through preserving about him in suitable wilderness areas representatives of the great variety of species still remaining in our native fauna.

### Some Results of the Survey's Wild-Life Research

Numerous local scientific investigations by the Biological Survey and specific portions of its larger undertakings have been completed at various periods of the past half century, but wild-life research as a whole is a continuing major project. Dealing as it does with living organisms, some of them highly migratory, and these and others in constantly changing environment, this work is ever confronted with new problems and with old problems apparently solved but arising in new guise. Thus, it can not be said that any phase of wild-life research has been fully brought to completion, but at the same time distinct progress and gratifying accomplishment have been and constantly are being registered.

Studying stomach contents of birds
Mr. W. L. McAtee at microscope.

### Research on Food Habits of Wild Life

The Biological Survey has made notable contributions to the literature of economic ornithology and to a lesser extent to that of economic mammalogy and herpetology. It has issued many publications on the food habits of mammals, some on reptiles and amphibians, and more than 250 on the food of birds. These publications on birds present in detail the economic status of about 500 species. Those of a popular nature on the economic status of birds and measures for attracting and protecting them are estimated to have been distributed in the past 48 years to the extent of more than 7,000,000 copies. With the more technical reports, these have had an untold influence for federal, state

Reptile studies by Dr. Remington Kellogg, formerly of the Survey.

and local bird-protective legislation and regulation and also for bird conservation internationally. Several of the reports involved the relation of birds to various insect outbreaks, and in addition to official and cooperative formal publications, a great volume of information on the status of wild species has long been disseminated through periodicals, the press, by radio, in manifolded leaflets and in the Bureau's day-by-day correspondence.

Other results of research on the food habits of birds have had wide application in solving problems in the introduction and protection of game, insectivorous and other useful birds and in the propagation of upland and aquatic game birds as well as in improving the natural food resources of birds. These studies have thus made possible a continuing utilization of the birds themselves and of their services and an enduring enjoyment of their beauty of motion, song and color. In addition, these studies have enabled the Survey to recommend measures ranging from local control of injurious birds to the care of aviary and ornamental species in captivity.

SKULLS OF FIELD MICE

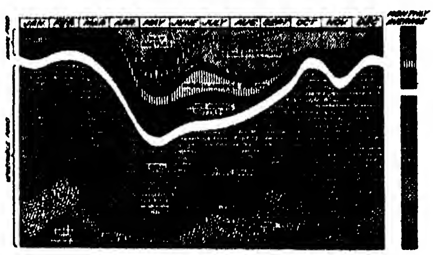
FROM OWL PELLETS TAKEN AT A ROOST IN SMITHSONIAN INSTITUTION TOWER, WASHINGTON.

Maintenance and increase of birds that have been demonstrated to be beneficial means increased destruction of insect pests and thus reduced crop losses. Local control of injurious birds has the same ultimate benefit. County agents have estimated that destruction of English sparrows in Utah by methods recommended by the Survey resulted in savings of $337,000 in three years. Similar control has been accomplished at the North Dakota Experiment Station and at certain Army posts, and control of birds destroying rice, other grains and fruit in California in some cases has reduced the damage to a tenth of what it was before.

TYPICAL FOOD OF CROW

AS SEPARATED IN STOMACH CONTENT EXAMINATION.

Research on the propagation of the plants found most important as wild-duck foods has assisted in building up a growing industry in the sale of these plants. Investigations for the improvement of wild-fowl feeding grounds has been a factor in increasing the value of many properties—in one case the gain was tenfold. Studies in improving the environment of upland game birds have set new standards for game-bird management, and the published report on one, the bobwhite quail, embodied the most comprehensive account of any American game bird that has ever been published. Acting on the findings and recommendations has doubled the production of quail on extensive southern



MONTHLY FOOD OF THE CROW

AS CHARTED BY THE BIOLOGICAL SURVEY.

holdings, and the financial gains alone would be a large figure, considering the high value set on quail hunting.

During the past three years examinations have been made of the waterfowl food resources on more than four million acres, and about a sixth of the total number of projects involved were recommended for acquisition by the government for migratory game-bird refuges. Though the saving of game birds realized by the establishment of these refuges is of economic as well as social and esthetic importance, it would be impossible to state the value in dollars.

### Research on Methods of Pest Control

Through research in methods of suppressing injurious rodents and predatory wild animals the Biological Survey has increased efficiency in the use of baits and traps, determined the minimum dosage for various species, improved mechanical preparation and packaging, and reduced the cost of control. Knowledge gained through this research has also made it possible to select, prepare and expose poisoned baits and to set traps so as not seriously to endanger animals other than those for which they were intended.

This phase of the Bureau's investigations has demonstrated that quail, pheasants, grouse and domestic poultry are surprisingly immune to strychnine poisoning and that grain baits can be so prepared and distributed as not to endanger birds of the gallinaceous group, the ones most likely to take these grain baits. The development of red squill as a poison specific for rats has made it possible to safeguard the home and the premises where rat control has to be undertaken. Safeguards also have been designed to minimize the danger to fur animals in areas where the ravages of predators must be curbed either by use of poison or by trapping. A special attachment for traps was invented in the Biological Survey, a device that keeps the trap from being sprung by animals or birds lighter in weight than the predator for which it is set.

Special studies are being made of thallium for local use against rodents that successfully resist other control methods—notably the California ground squirrel, a carrier of the bubonic-plague organism—and of treatments in case of any accidental human poisoning. Reported experiments have demonstrated that there is no danger of secondary poisoning from cooking and eating game birds that may have taken thallium grain baits exposed for rodents. This poison is used in restricted areas only, and there its use is closely supervised by state and Survey field leaders.

Improvements in control methods have resulted from findings as to the minimum lethal dosage required in baits for coyotes and other predators, which has had the effect of greatly reducing the quantity of poison used locally. A tablet also has been developed containing the proper quantity of poison for coyote and other baits. Cooperative rat-riddance campaigns have been simplified by the Bureau's introduction and demonstra-

SURVEY'S RESEARCH IN METHODS OF CONTROL

*Left,* Mr. J. C. Ward, making laboratory tests; *right,* Mr. F. E. Garlough, checking efficiency in field experiments.

U. S. RABBIT EXPERIMENT STATION OF THE BIOLOGICAL SURVEY, FONTANA, CALIF.

tion of ready-prepared and canned baits of varied composition, with red-squill powder as the effective agent. Other improvements that owe their origin to this part of the Survey's control-methods research include mechanical processing of strychnine baits to conceal the bitter taste and thus render them more acceptable, and development and application of catnip-oil and other scents as lures to traps placed for mountain lions, bobcats and other predators. Other accomplishments in control-methods research have ranged from improvements in methods of trapping wolves in the United States and Alaska to the devising of means for repelling bats from obnoxious roosts established in human dwellings.

The importance of research in pest control is appreciated from the benefits accruing to farmers and stock growers, foresters and game protectors, warehousemen and the individual householder. Rodent pests each year cause enormous losses in farm crops, forest and fruit trees and in range forage and stored products; and predators commit serious depredations on cattle, sheep, pigs, goats, poultry and wild game animals and birds. Compared with these losses, the cost of the research is insignificant.

FOX PENS
AT THE SURVEY'S FUR ANIMAL EXPERIMENT STATION, SARATOGA SPRINGS, NEW YORK.

### EXPERIMENTS IN FUR-ANIMAL PRODUCTION

The Survey's research in fur resources, while of special interest to trappers, fur farmers, legislative committees and wildlife conservationists, is of benefit also to the fur trade and to the consumer of fur. Many of the problems confronting these various groups have found at least partial solution in the technical information coming from the Bureau's research. About 80 foreign countries contribute to the fur annually consumed in this country, which aggregates more than that of any other country in the world. With our consumption greater than our production, and with the native stocks constantly decreasing before human occupation of their haunts, it becomes necessary for scientific research to bridge the gap between domestic supply and demand. Accordingly, experiments in fur farming were undertaken by the Survey.

At the two fur-animal experiment stations maintained by the Biological Survey, one in New York, established in 1916, the other in California, in 1927, many species are studied—foxes, martens, minks, badgers and other native fur-bearers and fur rabbits. The results are made available by bulletins and other means of public information, chiefly for the benefit of fur farmers and of persons who contemplate engaging in the industry. Throughout, the Survey's work in fur production has had the close cooperation of educational institutions, state conservation departments, private organizations and associations of the fur trade. In 1930 the Bureau placed an exhibit, supplemented by a special pub-

lication in English and German editions, at the International Fur Trade Exposition and Congress, at Leipzig, Germany, with results mutually beneficial to this and to other countries participating.

Studies at the Bureau's experiment stations and at many fur farms throughout the country have developed important information regarding the several species raised for fur and have resulted in reduced costs of production, improvements in pens, dens and sanitary housing and elimination of wasteful and inhumane methods. Anatomical data regarding the many varieties of fur animals have been placed on record, and the mating and gestation periods of the marten have been established, thus for the first time making it practicable to breed this valuable fur species in captivity. Investigations of pelt value have included studies of the effect of sun and shade on fur quality, and a genetic basis has been established for control of color phases of foxes along Mendelian lines.

Research in rabbit production has included studies of quality and texture of the fur of various breeds, the beneficial effects of crossbreeding on both meat and fur-producing rabbits, and the influence on growth to market age by feeding various rations, including hays, grains, mashes and cod-liver oil and other supplemental feeds. The importance of these investigations is evident from the large investments in the business, particularly in the Pacific Coast states. Rabbit meat has become a staple in many markets, and rabbit pelts are being used in the fur trade in greater quantity than those of any other fur animal.

COLOR PHASES OF FOXES

AS DEVELOPED BY THE SURVEY ON MENDELIAN LINES.

### Wild-Life Disease Investigations

Critical studies of wild species propagated under controlled conditions and observations of wild-caught individuals have served to emphasize that both are subject to a wide variety of diseases. Research to provide a basis for controlling or preventing outbreaks is important, therefore, to the fur and game farmer and to those concerned with the conservation of the species in the wild. The Bureau's wild-life disease investigations have been the means of reducing losses and enabling many propagators to continue their occupation on a profitable basis.

As a result of studies of bacterial, parasitic and other wild-life diseases by the Survey and its cooperators at the University of Minnesota and elsewhere, a number of epizootics have been stamped out on fur and game farms. Such elimination has saved many propagation projects from bankruptcy, for when abnormal conditions occur in wild animals or birds they are frequently of such severity as to wipe out large portions of the exposed populations in the wild as well as a high percentage of the stock on game and fur farms.

RESTRAINING FOX FOR DISEASE TREATMENT.

Administrators of wild life on private estates and preserves and on extensive areas in the wild are more and more being acquainted with the seriousness of disease outbreaks in the stock for which they are responsible. Information as developed by the Survey is made available for their use to aid in eliminating as many of the hazards as possible. It is necessary, however, that such research proceed and that investigations be made sufficiently extensive for satisfactory control under all circumstances.

Facts already developed show that there are cycles both of abundance and of scarcity in many species in the wild—rabbits, for example—and that local depletions frequently result from disease, the spread of which is facilitated where the victims are densely crowded. Some of these wild-life diseases are communicable to man, including tularemia, rabies, bubonic plague and spotted fever. A thorough knowledge of these diseases of wild life facilitates the application of protective and remedial measures.

One of the most important results of the Bureau's research in wild-life diseases was the discovery of the cause of the celebrated western wild-duck sickness, which in many areas has caused the death of more wild fowl in a season than fell before the guns of the local hunters. At first considered to be caused by excess alkalinity of certain waters, it was finally developed by the Survey to be of bacterial origin, a form of botulism caused by *Clostridium botulinum*, type C. The remedy indicated is proper control of water level and movement and in some cases treatment of rescued birds by change of food and environment for a period prior to release.

Other discoveries have had to do with a condition on fox farms formerly termed generally "distemper" but now known to be several distinct diseases, among the most disastrous being infectious fox encephalitis and fox paratyphoid. It is not yet known how prevalent these diseases are in the wild, but under controlled conditions their incidence appears to correspond to the density of the fox population. Comprehensive studies also have been made of bob-white quail, their diseases and methods of control.

PINTAIL CURED OF BOTULISM
RELEASED AT FIELD LABORATORY BY MR. E. R. KALMBACH.

In addition to their infectious diseases, many species are subject to rickets and other nutritional maladies, to lead and phosphorus poisoning contracted when picking up shot and particles of the chemical with grit on their feeding grounds and to losses from water pollution. So many are the dangers menacing wild life in contact with the human population that it is little short of amazing that so many of the species still survive. Until the fact-finding investigations undertaken by the Bureau have been sufficiently extensive, adequate control measures can not be recommended in all cases. In the interim, thoughtful administration of our wild-life resources calls for proper management of habitats in the wild and strict measures of sanitation on fur and game farms. With better fundamental knowledge of requisite sanitation and of causative organisms will come a more adequate system of disease prevention and treatment.

### Studies of Faunal Distribution and Relationships

Scientific investigations of wild-animal life, continued by the Survey for nearly half a century, have resulted in the accumulation of extensive and systematized files and in the publication of more than 800 formal reports, official, and in scientific periodicals, including many monographs on the North American fauna and faunal studies of states and other large areas. Such basic information on the classification, distribution and habits of species enables the Survey to plan effectively its other work in wild-life conservation and control and to cooperate with game-conservation boards, agricultural and live-stock associations, educational institutions, experiment stations and other organizations. In addition to its provisional life-zone map of North America, the Survey has published detailed maps of the life zones of many of the states, thus bringing to higher perfection the map of the continent as biological surveys are completed over large areas.

Big-game conditions have been studied with a view to recommendations for improving environmental factors on federal preserves and national forests and parks, the chief species involved being deer (on the Kaibab Plateau, Arizona, and in Pennsylvania), elk (Yellowstone Park region and adjacent forests), wild life generally in many national parks, and antelope, mountain sheep, caribou and moose. The relationships of these animals and of predators and rodents to their habitat and to the industries of agriculture and stock-raising are constantly being observed and studied.

CHECKING GEOGRAPHIC DISTRIBUTION RECORDS OF MAMMALS

Mr. E. A. Preble studying map.

One result of the regional biological surveys has been the assembling of collections of mammals and birds and of information about them that are of incalculable scientific value and afford a practical basis for determining the occurrence, distribution, habits and needs of species that are of importance economically and otherwise. These data have been used in formulating treaties and other agreements looking to the protection of migratory birds, in furthering educational programs involving sound agricultural development and land utilization and in determining administrative policies in wild-life management.

Early in the history of the Biological Survey, Dr. C. Hart Merriam, the chief, developed and applied the laws of geographic distribution, based on temperature, altitude and slope exposure, a result of which has been the Survey's mapping of the natural life zones of the continent, the details of which are still being filled in from time to time. Developments of the life-zone research have been evidenced in studies of animal and plant ecology, and in connection with the study of factors limiting the range of crops and the areas suitable for fur farming. Research in geographic distribution has also resulted in the announcement of laws on the speed of bird migration northward in spring, as correlated with successive isotherms. Studies of bird movements and other phases of their life histories are being supplemented through use of data on bird banding, the central records of which, and the direction of activities in North America are in offices of the Biological Survey.

From the Survey's mammal research have been evolved new methods of field collecting, museum labeling, arrangement and care of specimens, training field assistants and publishing specific descriptions and generic monographs. Prior to the entry of the Biological Survey into the field only the most obvious types had been described, and hundreds

WATERFOWL STUDIES

226 PINTAIL, REDHEAD AND MALLARD DUCKS TRAPPED BY BIRD-BANDING COOPERATOR OF THE SURVEY.

SKULLS IN THE BIOLOGICAL SURVEY MAMMAL COLLECTION

BEING CLASSIFIED BY DR. H. H. T. JACKSON.

of specimens formerly unknown are now named and recorded, with type specimens available in study collections. So great has been the impetus to mammal study and so numerous have been the additions to the recognized varieties of mammals, due to more general recognition of the value of distinguishing characters, based on color and peculiarities of skull and teeth, that the mammals are now almost as well known as the birds. In fact, a confrere once remarked that Merriam had named more animals than did Adam!

The standards set by the early work of the Survey have resulted in the accumulation of a wealth of material in the museums of the country, of much better quality than had ever before been available. The importance of maintaining and building up the Survey's collection of scientific specimens is evidenced by the fact that these enable the Bureau to identify specimens and even fragments that are of economic importance, including determination of identity of species that carry disease, destroy or protect crops, or are otherwise detrimental or useful to man, sometimes for identification to prevent fraud in bounty payments. The collection is also used in scientific investigations by the Bureau's staff and by cooperating institutions.

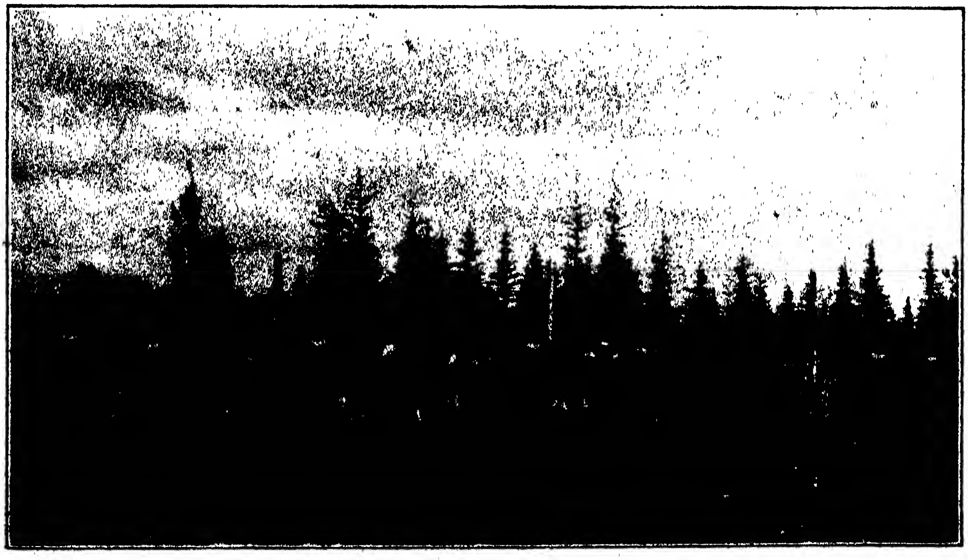
SCIENTIFIC BASIS FOR BIRD PROTECTION

In the field of investigations of migratory birds, the work of the Survey provides a rational basis for conserving a natural resource that has important relations to agriculture and forestry and one that supports large investments in recreational facilities, including hunting, camping, transportation and the production of outing equipment, and provides large financial returns to land and marsh owners, guides and others rendering services to vacationists, sportsmen and other outdoors men.

Through extended surveys of migratory birds in the United States and adjacent countries, the Bureau has assembled a vast amount of information, on which it has based reports, charts and maps for use in drafting regulations under the Migratory Bird Treaty Act and in educational work. Bulletins have been issued to make available information on the economic value of birds, abundance of waterfowl, conditions on their breeding and wintering ranges, their migration routes and the effect on their future of drainage, water pollution, drought, food supply and hunting practises. On such basis, the United States, nationally and by state action, has built up the best system of bird-protective laws on the statute books of any nation, and the Federal Government is providing on marginal and other lands a system of inviolate sanctuaries for wild fowl.

Establishment of bird-protective laws on a research basis has produced wider appreciation of the importance of respecting seasons when the birds have paired off for breeding. Two outstanding accomplishments under the federal laws protecting migratory birds have been the abolition of spring shooting and of the sale of ducks, geese and other waterfowl.

Studies of the wild life of forests, intensified in recent years, are providing exact knowledge of forest species, their life histories, abundance and ecological relationships, including their effect on forest pests, on planted seeds and seedlings and on forage production on forest-grazing areas, soil fertility and erosion. Potential improvements of forests by



PART OF HERD OF MUSK-OXEN

TRANSPORTED TO ALASKA FROM GREENLAND FOR RESTOCKING PURPOSES.

HERD OF ALASKAN REINDEER

BEING STUDIED BY SPECIALISTS OF THE BIOLOGICAL SURVEY.

wild life include the planting of colonies of beavers to demonstrate methods of improving water storage, increasing fish and fur production and checking run-off and erosion.

### Investigations in Reindeer and Musk-ox Production

Among research accomplishments by the Survey in Alaska have been the successful reintroduction of musk-oxen in the territory by transportation from Greenland and improvement of conditions affecting the reindeer herds. Musk-oxen, once important in the Alaskan fauna, were exterminated in the territory shortly before European occupation. The present effort is to rear the introduced young animals at an experiment station until they reach breeding age, so that they may reestablish the species in the northern parts of Alaska. Under practical management on the extensive grazing areas of the region they may become an important game or domestic resource.

Alaskan reindeer, introduced from Siberia by the Bureau of Education more than 40 years ago, have rapidly increased and now present new and pressing problems that affect the animals themselves, the grazing resources and the economic and social welfare of the native and white population. Biological Survey investigations in coastal, insular and interior Alaska are aiding owners to cope with the parasitic and other diseases of reindeer, to adopt improved methods of herding and range management, and through proper care and selective breeding, to improve the quality of the animals for meat production. Experiments in crossbreeding with native caribou have been conducted successfully with a herd maintained on Nunivak Island, the crossbred animals averaging materially heavier and having better conformation for meat than either of the parent forms. In the reindeer herds the native and white population have an important industry that means much both industrially and socially. In the improved practises developed and recommended by the Biological Survey they have a basis for an enduring industrial civilization.

# WEST INDIAN HURRICANES[1]

By Dr. MELVILLE T. COOK

PLANT PATHOLOGIST, INSULAR EXPERIMENT STATION OF PUERTO RICO

HURRICANES in the West Indies have been known since the coming of the white man. In fact, the name "hurricane" is derived from an Indian word which the Spaniards adopted and which was taken by the English with slight modification of pronunciation. The early records show that these storms were dreaded by the Indians and settlers. Columbus met with one of these storms on his first voyage, which forced him to take refuge in a harbor of Santo Domingo. On his second voyage, while at anchor at Cape Santa Cruz (July 16, 1494), "a violent hurricane occasioned the admiral to declare that nothing but the service of God and the extension of the monarchy should induce him to expose himself to such dangers." July 1st, 1502, he suspected the approach of a hurricane and asked permission to enter a harbor of Santo Domingo, which was refused. He then put to sea and within the next twenty-four hours, twenty ships and all on board were lost. Columbus describes this storm as follows: "The gale was terrible, and in that night my vessels parted company, every one expecting death, and each considering it certain that the others were lost. With the exception of Job there never was a man who would not have died in despair: When to save my life and that of my son, brother, and friends, I was at such a time forbidden the harbors, which by God's permission, I had gained for Spain, sweating blood. The vessel in which I was, weathered the gale marvelously; it pleased God that she received no damage whatever. My brother was in the unsafe vessel, and, next to God, was the means of saving her. In this gale we made Jamaica." Many hurricanes have been recorded since that time, and the average has been about five per year for the entire Caribbean area. Most of these storms do little or no damage, because they never strike land, but some of them have been very destructive of both property and life and the cause of much suffering among the survivors. In fact, the suffering was so great that it was sometimes necessary to use military force to prevent the early Spanish settlers from returning to Spain.

The last destructive hurricane in Puerto Rico, previous to the Spanish-American War, was the San Narciso,[2] of October 29, 1867. The first hurricane after the Spanish-American War was the San Ciriaco, August 8, 1899. The loss of life and property at that time was enormous. It was estimated that 3,000 people were killed or drowned. The United States Weather Bureau was not so well established in the West Indies then as at present, and the communications by telegraph and telephone were very poor. The storm came on the unsuspecting people in the night and was accompanied by a heavy downpour of rain. The rivers rose rapidly and many people were carried out to sea. Following that date there were a few small but no severe hurricanes in Puerto Rico[3] until September 13, 1928, when we were struck by the San Felipe, which came in the daytime and swept across the island diagonally from the southeast to the northwest (Map 6).

[1] The meteorological data have been verified by a member of the U. S. Weather Bureau. Photographs by courtesy of the U. S. Forestry Service.

[2] It is the custom of the Spanish-American people to designate these storms by the name of the Saint on whose day they occur.

[3] In August, 1926, a hurricane caused rather heavy losses over a small area of the southwestern part of the island.

The path of this storm was 150 or 200 miles wide and the danger zone 50 or 75 miles wide. The maximum velocity at San Juan was between 9 A. M. and 3 P. M.

The next hurricane was the San Nicolás, which struck the island between 9 P. M. and midnight, September 10, 1931. This was of very small diameter and very mild, as compared with the other two. It followed the full length of the island, the vortex being a little north of the north coast and the velocity about 90 miles per hour.

The third was the San Ciprián, which swept the north part of the island between 8 P. M., September 26, and 6 A. M., September 27, 1932. The path of this storm was about 50 miles wide and the velocity about 120 miles per hour. The destruction was very great, but was less than the San Felipe, because the path was not so wide.

These storms originate in the Atlantic Ocean usually during the months of August and September, although there are many records for July and October and some few for other months. They usually sweep across the Caribbean Sea or turn northward and come to an end on the continent or in the North Atlantic Ocean. If they strike land, we hear about them, but if they blow themselves out at sea without destruction of shipping they become records for the Weather Bureau only. These storms have two movements, a rotary movement (counter clockwise[4]) in which the velocity may be as great as 150 miles or more per hour, and a forward movement, which may be as slow as eight miles per hour or even less under certain conditions. There is always a small calm area (the vortex) in the

[4] Hurricanes south of the equator blow in the opposite direction.

BUILDINGS AT THE FORESTRY STATION AFTER THE SAN CIPRIAN

NOTE THE STEEL FLAG POLE IN THE FOREGROUND.

center. The velocity is greatest next to this calm area and gradually decreases towards the circumference. The region in the path of the vortex is struck by the outer part of the storm, which becomes more and more severe until the calm area arrives when there is a sudden cessation for a few minutes to a half hour or more depending on the size of the storm. With the passing of the calm area the region is struck by the second half of the storm which is blowing in the opposite direction. The points affected by the storm not crossed by the vortex experience a gradual rise and fall in the velocity of the wind.

Four other hurricanes of recent years that should be mentioned are the one that struck Havana October 20, 1926; the one that struck Santo Domingo September 3, 1930; and the one which struck Belize August 15, 1931. All these hurricanes were the causes of heavy losses of property and lives and are fresh in the memory of the readers. The fourth is the one that struck Cuba November 9, 1932, and was accompanied by a storm wave which killed or drowned about 2,500 persons. Two hurricanes struck Florida in 1926, and the one that struck Havana was felt in the southern part (see maps 1 and 5).

The paths of the storms of the past four years are very interesting. There were four storms in 1928 (Map 2). The first passed to the east of the West Indies, traveled northwest and did little or no damage. The second was almost parallel and to the west of the first and did very little damage. The third passed over some of the Lesser Antilles, moved almost due west and was of very little importance. The fourth, which was the San Felipe, took the same gen-

RESULTS OF THE SAN CIPRIAN.

NOTE THE FOLIAGE STRIPPED FROM THE TREES. TWO ROYAL PALMS ARE IN THE FOREGROUND.

COCONUT PALMS AFTER THE SAN CIPRIAN.

IN MANY PLACES THE PALMS WERE SNAPPED OFF CLOSE TO THE GROUND.

eral direction as the first and second but between them the greater part of the time.

There were three hurricanes in 1930 (Map 3). Two were of little importance, but one struck Santo Domingo and caused great losses of both lives and property.

There were five hurricanes in 1931 (Map 4). The first traveled almost due west and struck Belize with great loss of life and property. It was the most destructive of any during that year. The second swept to the north, a little west, over Puerto Rico, and was of little importance. The third originated well to the north, traveled almost due west, across Santo Domingo and the Isle of Pines, turned northeast, crossed Florida and died in the Atlantic Ocean. The fourth followed the course of the first very closely and did very little damage. The fifth was the San Nicolás, which also traveled almost due west, brushed the north coast of Puerto Rico and Santo Domingo.

There were four hurricanes in 1932 (Maps 5 and 6). Two were of little importance. The third was the San Ciprián, which struck Puerto Rico and was very destructive. The fourth struck Cuba, killed about 2,500 people and caused heavy loss of property. This hurricane came very late in the season and its forward movement was very slow, but it increased in force after turning north.

The approach of a hurricane is preceded by short periods of wind and rain, which become longer, stronger and more frequent until they merge into a continuous storm. The storm roars, howls and shrieks, but the most characteristic sound is a very shrill whistling. The intensity of the storm varies after it reaches its maximum velocity. The noise due to falling buildings, uprooting of trees and other destruction depends largely on the location, but the noise made by the storm is usually greater than that due to the destruction.

The writer was located about 20 miles northeast of the vortex of the San Felipe hurricane, about 6 or 8 miles south of the vortex of the San Nicolás and about one half mile or less north of the vortex

of the San Ciprián. Squally weather which preceded the San Felipe started about 4 P. M. the day (Wednesday) before and increased in intensity until 9 A. M. the following day. From that time until about 3 P. M. the velocity was at its maximum of about 150 miles per hour. Heavy pieces of zinc roofing were ripped from the houses and carried into the air like sheets of paper. This was followed by the woodwork. These and many other articles flying through the air were a source of great danger to persons and live-stock without shelter. The streets and roadways very soon became a tangle of broken trees, poles and wires. The writer lost a part of his roof a little before 3 P. M. The storm subsided rapidly after 3 P. M. and many people were on the streets by 5 P. M., but squally weather continued until 6 A. M. the next day. The contents of nearly all houses were damaged and in some cases entirely destroyed. The more unfortunate people utilized every possible kind of shelter from flying objects; under beds, tables, kitchen sinks, and occasionally under the floors of the houses. Sometimes very substantial buildings would be severely damaged, while small frail buildings beside them would be very slightly damaged. A steel flag pole (without flag) was bent at an angle of 45 degrees.

The San Nicolás was preceded by squally weather and came with a velocity of about 90 miles per hour at about 9 P. M. and lasted until near midnight. Many objects were blown against our house, but we had very little damage. We were less than one half mile from the vortex of the San Ciprián hurricane. This was preceded by squally weather and reached its maximum of 120 miles or more at about 11 P. M. It began to subside about 3 hours later. Many heavy objects were blown against our house, and we thought the entire roof had blown away. Much water came in and we were kept busy moving furniture and covering various articles. After the storm began to subside we could see by the flashes of lightning[5] that the roofs of many of the neighboring houses had been blown away, but with the coming

[5] There is a belief among the people that when lightning accompanies a storm, it will not be a hurricane. This was an exception. The literature shows that a few hurricanes have been accompanied by lightning.

A SMALL SUGAR CENTRAL THAT WAS DESTROYED BY THE SAN CIPRIAN.

of daylight we found that we had lost a small part of our roof. However, both roof and ceiling were raised an inch in the front part of the house. One of the neighbors who had a lantern called and we visited a few of the neighbors and rejoiced to find that there were no fatalities among them. One of our neighbors who lost his roof was compelled to shelter his family with a bed mattress for a time and then sought refuge in the servants' quarters, which were not damaged. I found him and his wife and five little children (two with measles) there later in the morning. With the coming of daylight we found that most of the houses in the neighborhood were almost or completely unroofed. Roofing nails which were carried for 100 yards were shot through my windows like bullets.

With the coming of daylight the writer made a short tour of investigation into a section occupied by the very poor peons. Nearly every house was in ruins and the poor people were trying to salvage a few of their meager possessions. The philosophy of these people is surprising to any one who does not know them. They have very little of this world's goods to care for and so long as they do not suffer personal injuries they do not worry. We could hear them hammering as soon as it was light enough to see, and within a few hours practically all these people had temporary shelters which they constructed from the ruins.

In this connection it may be well to say that statements concerning the losses of property are likely to be misunderstood by the people of the north unless they are familiar with the character of our residences. Many of the old Spanish buildings are still standing. They have very thick walls of masonry and flat tile roofs without projecting eaves. They were not damaged to any great extent. The American bungalow type of house, with steel reinforced walls and corrugated galvanized roofing, has become very popular in recent years. The walls of these residences stood, but

AFTER THE SAN CIPRIAN.

NOTE THAT THE FOLIAGE IS STRIPPED FROM THE TREES.

NOTE THE SMALL SHELTER CONSTRUCTED FROM THE RUINS.

most of the roofs were blown partly or completely away. This was partly due to the failure to anchor the roofs properly and partly to the fact that the projecting eaves are exceptionally favorable for hurricane damage. Most of the frame houses were damaged, some of them beyond repair. The great majority of the people are very poor (as is the case in all tropical countries) and live in frail little houses constructed of fragments of lumber, old roofing, old boxes, palm leaves, etc. These houses are destroyed in great numbers. The money value is very small, but they are of such simple construction that most of them can be rebuilt within a few days.

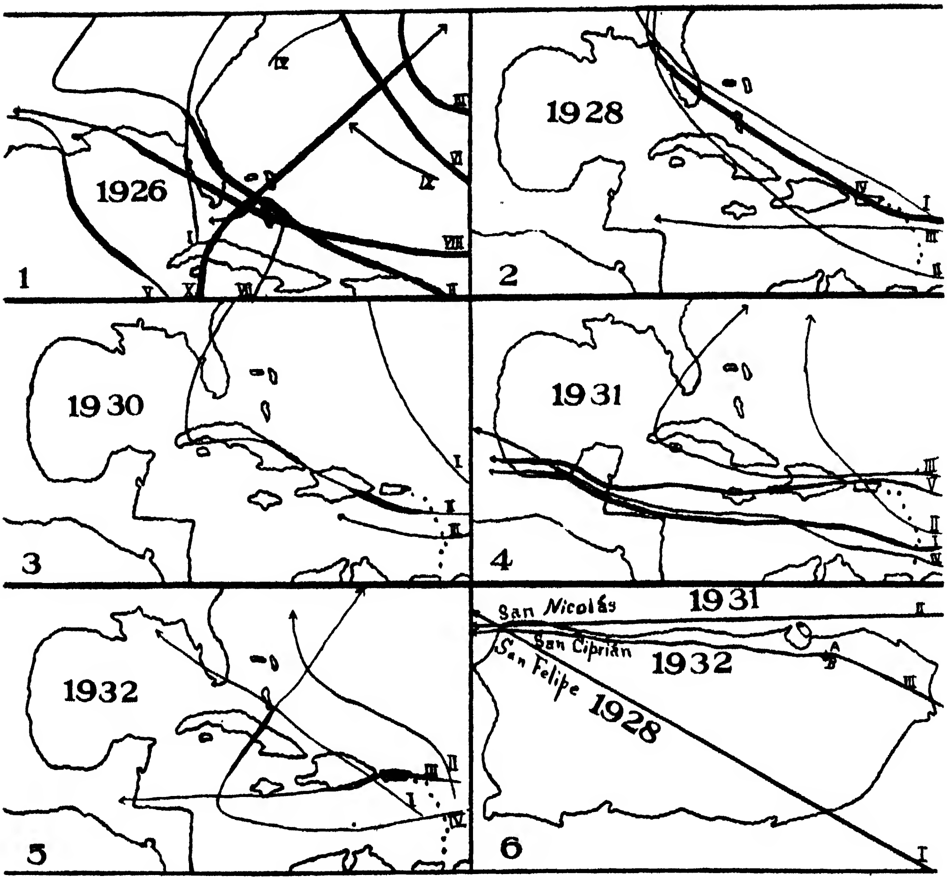
Thousands of trees were broken or uprooted. The leaves were stripped from many species of trees and shrubs and the country resembled a northern landscape in midwinter. Thousands of coconut palms were uprooted or snapped off near the level of the ground. The tops of those that remained standing were so torn and mangled that they presented a sorry sight. The luxuriant growths of tropical forests were torn and tangled in a frightful manner.

Sugar-cane is our most important crop. Some of it was uprooted, some broken off at various heights, some damaged by water and the soft parts of the foliage stripped from practically all of it. In many cases it was necessary to plow out and replant. Broken canes sprout from the lateral buds and the sugar content is greatly reduced. The down and tangled cane is difficult to cut and the cost is increased.

Practically all the citrus fruits were blown from the trees and the ground was covered with fruits that would have been a joy to our northern markets. Many of the trees were uprooted or broken and many of the packing houses were partly or completely destroyed.

The coffee crop, which was just ready for gathering, was completely destroyed by the San Felipe and injured by the San Ciprián in some places. The coffee berries were whipped from the plants and the plants were damaged by the storm or by branches which were blown from the shade trees.

Banana plants were broken off near the surface of the ground and the fruit destroyed. Since it requires 12 to 15




MAPS SHOWING WEST INDIAN HURRICANES IN RECENT YEARS.

MAP NO. 1 (1926) SHOWS TEN STORMS; FIVE OF THEM WERE VERY SEVERE AND THREE OF THEM WERE DESTRUCTIVE. STORMS NO. II (JULY 24 TO AUGUST 1) AND NO. VIII (SEPTEMBER 15 TO 22) STRUCK FLORIDA. NO. X (OCTOBER 19 TO 22) CAUSED HEAVY LOSSES IN CUBA AND WAS FELT IN THE SOUTHERN PART OF FLORIDA. MAP NO. 2 (1928) SHOWS FOUR STORMS. NO. IV (SEPTEMBER 11 TO 17) WAS THE SAN FELIPE, WHICH WAS VERY DESTRUCTIVE IN PUERTO RICO AND SEVERE IN FLORIDA. MAP NO. 3 (1930) SHOWS THREE STORMS. NO. II (SEPTEMBER 1 TO 13) WAS VERY DESTRUCTIVE IN SANTO DOMINGO. MAP NO. 4 (1931) SHOWS FIVE STORMS. NO. I (AUGUST 10 TO 18) CAUSED HEAVY LOSSES OF LIFE AND PROPERTY IN BELIZE. NO. V (SEPTEMBER 8 TO 15) WAS THE SAN NICOLÁS, WHICH WAS QUITE SEVERE IN PUERTO RICO AND SANTO DOMINGO. MAP NO. 5 (1932) SHOWS THREE STORMS. NO. III (SEPTEMBER 26 TO 30) WAS THE SAN CIPRIÁN, WHICH WAS VERY DESTRUCTIVE IN PUERTO RICO. NO. IV (OCTOBER 31 TO NOVEMBER 11) WAS VERY DESTRUCTIVE IN CUBA. MAP NO. 6 SHOWS THE CENTERS OF THE PATHS OF THREE HURRICANES IN PUERTO RICO. NO. I IS THE SAN FELIPE, SEPTEMBER 13, 1928. NO. II IS THE SAN NICOLÁS, SEPTEMBER 10, 1931. NO. III IS THE SAN CIPRIÁN, SEPTEMBER 26, 27, 1932. THE WRITER WAS LOCATED AT A, WHICH IS JUST NORTH OF THE TOWN OF RIO PIEDRAS (B).

months for a plant to produce fruit, this source of food was greatly reduced.

The following figures taken from the United States Weather Bureau Reports may be of interest to the reader:

| | S. Ciriaco | S. Felipe | S. Nicolás | S. Ciprián |
|---|---|---|---|---|
| Loss of life | 3000 | 300 | 2 | 225 |
| Lowest barometer at San Juan | 29.23 | 28.81 | 29.17 | 28.95 |
| Hurricane winds at San Juan for period of | 3 hours | 12 hours | 2 hours | 6 hours |
| Maximum wind velocity at San Juan | 75 miles | 150 miles | 90 miles | 120 miles |
| Maximum rainfall | 23 inches* | 29 inches† | 5 inches | 16.70 inches |
| Advance warning | 19 hours | 36 hours | 40 hours | 18 hours |
| Property and crop losses | $20 millions | $50 millions | $200,000 | $30 millions |

* Adjuntas records. † Maricao records.

of the house so as to permit the wind to pass through. In fact, as soon as the direction of the wind can be determined, a window or door should be opened on the leeward side. After the storm was

A great tragedy usually has its comic features, and this has been true of the hurricanes that we have experienced. A few of them may be of interest to the reader. Some people took refuge in homes which they considered stronger than their own. The storm destroyed the houses of refuge and their own homes stood. A family took refuge in a closet. When the storm subsided they looked up and discovered that the second story was gone. A house was destroyed and the family took refuge in the children's play house, which was uninjured. A family went into the bath room; when the storm subsided they opened the door and found that all the house except the bath room had blown away.

It is impossible to understand the force of these wind storms without having passed through at least one of them. Therefore, we did not take the approach of the first one very seriously; but when we heard of the approach of the second, there was a feeling of dread rather than fear. Every one who has ever experienced one of these storms begins nailing boards over the windows and doors. If a window or door caves in, the wind is almost certain to lift the roof unless a window or door is opened on the lee side well started, we lost the feeling of dread and were kept busy moving various articles so as to protect them from water that came through the roof and ceiling. As soon as wires began to break, the electric power was shut off and in the San Ciprián we were in total darkness, except for candles. Finally, the water came through in such quantities that it was impossible to keep the candles burning. By that time practically everything in the house had been moved into the dining room. We sat down and waited for the storm to subside.

The illustrations do not show the extreme damages resulting from the hurricane. The inconveniences following the storms are very great. Workmen open the main roads in a very short time, but the side roads and streets may be blocked for several days. The contents of the house must be dried as soon as possible, and this is not easily done, because showers of rain may be frequent and with little or no warning. It may be a month or more before the electric and telephone lines are working. But gradually conditions become normal and the love for the tropics returns.

# WAVE TRANSMISSION AS THE BASIS OF NERVE ACTIVITY[1]

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WHEREVER we look in the world of matter and events outside ourselves we find that oscillations and wave motion have a significant, often a dominant, rôle. It is not, therefore, astonishing to find that waves play an important part in ourselves also. Let us discuss the nature of these waves.

Most of the well-known oscillations with which physics is concerned are a consequence of the reaction with one another of properties analogous to inertia and elasticity. A moving or a changing system tends, on the one hand, to continue in its state of motion because it possesses, for example, mass or inductance: even social, economic and intellectual changes are endowed with such characters of inertia, which keep them going when they have passed a true position of equilibrium. On the other hand, such systems, if they are to continue to exist, if they are not merely to be dissipated, must possess converse properties which tend to bring them back once they have overshot their equilibrium: such properties in physics are elasticity and electrical capacity, in finance and politics are fear and conservatism. These exercise a constraining force increasing with the displacement from equilibrium, and ultimately reverse the motion or change, and the same oscillation is repeated in the opposite direction.

There is, however, another type of oscillation, less commonly discussed in physics or mechanics but none the less well known in every-day affairs: that which depends upon a discharge taking place when some limiting potential or intensity is reached. For example, (1) water falling into a tank equipped with a siphon will come out in rushes whenever it rises to a certain level. Or again, (2) a population in which an epidemic of measles can not start because of the number of people in it who are immune, having had the disease already, will gradually become less immune as time goes on, and finally an epidemic, a wave, of measles will sweep through it. (3) A neon lamp with a parallel condenser, in series with a resistance and a source of electromotive force, will discharge at regular intervals, namely, whenever the potential difference across the condenser reaches a certain critical value. This type of oscillation does not depend upon inertia reacting with elasticity. Its essential nature is (a) that some state, some potential, some intensity, is built up by a continuous process, and the condition becomes less and less stable until one is reached in which discharge must take place, and (b) this discharge, once started, forms a path for itself by which (as in a siphon or an electric arc) further discharge is facilitated until what has been built up gradually has been broken down and the process begins again. This type of oscillator (sometimes referred to as a relaxation oscillator) is the one with which alone we are concerned in physiology.

Waves may be transmitted on the same principle in a system extended in space. An unstable state is gradually built up until at some point, either through an external agency or by some intrinsic process, discharge is begun, which starts and facilitates a discharge in neighboring regions which themselves discharge, and so a wave is propagated. Such waves will occur periodically if at some

[1] Address before the Century of Progress Meeting of the American Association for the Advancement of Science, June, 1933.

region the potential at which discharge begins is less than that finally attained by the continuous process of charging: they will require, however, an external agency (a "stimulus") to start them if the unstable condition, the limiting potential, is not attained spontaneously. Models of such waves will occur to all of you: their principle is obvious. I have emphasized it because the waves on which nervous activity is based appear to be of this type. All detailed theories of nervous transmission may well be wrong, but this general idea of it, involving building up and discharge, is almost certainly right.

One of the chief characteristics of living systems, particularly of animal ones, is "excitability"—the property of reacting to a small change in the environment, or even in the system itself, by a greater response. This excitability is zero immediately after a response has occurred: the cell or organ passes through a completely refractory stage: its potential is at first not yet high enough for any further discharge to take place. After the completely refractory phase, it passes into one in which its excitability is lower than normal, in which stronger provocation than usual is required to produce a discharge. Finally it returns to its initial state. This state may be one in which spontaneous discharge occurs, or, on the other hand, discharge may require what is known as a stimulus to start a path for it. In a single organ the final level may be above or below that of spontaneous instability, according to the circumstances. The greater the constraint on it the more quickly, in general, it reaches the level of discharge, the greater the frequency of the so-called "response." The time for the complete cycle from the absolute refractoriness following a response to complete recovery ready for further discharge varies greatly from one organ or cell to another. It may be measured in thousandths or in fractions of a thousandth of a second, it may be measured in seconds or even minutes.

An ordinary nerve trunk is a bundle of separate fibers along which messages are sent. The unit, the nerve fiber, is not normally spontaneously unstable, but it can be excited by various agencies, particularly by an electric shock, after which a wave starts off from the point excited and travels to the end of the nerve. Once the discharge has been started it persists and travels in space. If a nerve be injured persistent spontaneous discharge may occur. An ordinary muscle, which is a bundle of separate fibers which contract and do mechanical work, is not spontaneously excitable, though it also can be stimulated by various agencies; it is easy, however, by a slight change in the salt content of its environment to render it state unstable, so that regular oscillatory discharges take place in it; these can be recorded electrically and result in visible twitchings of the fibers. The heart muscle, on the other hand, has naturally an inherent rhythm of its own: after a beat it is at first completely refractory, then for a period it can be excited, *e.g.*, by an electric shock, finally it beats again of itself. Something in it is gradually restored, until a potential is reached at which discharge must occur. This restoration is quicker in one region than in another, and since the discharge once started is propagated as a wave, the rhythm of the heart as a whole is set by that of the region in which restoration is quickest. All parts of it, however, have the same property of spontaneous discharge, and even an isolated portion of heart muscle will beat of itself, though more slowly than when attached to its natural pace-maker. If its mechanical tension be diminished enough the spontaneous beats may disappear; the lack of mechanical constraint somehow raises the level at which instability is reached and at which spontaneous discharge occurs.

It is necessary sometimes for a physiologist, as Rutherford was once heard to say, to make a noise like a physicist. Physics is not indeed the only, or even the chief, way of approaching physiological problems, but it has among its advantages that of providing at such a conference as this a language by which other people, for example, engineers, physicists and chemists, may be introduced to physiology. Through no fault of their own, no doubt, many people, people of high scientific standing, have never had any experience at all with that subject. They often have very absurd ideas about it. They do not perhaps go so far as the lady who, to a doctor trying to explain to her what was wrong with her, made the appeal, "Don't, Doctor, don't—I like to think I am lined with pink satin." But they are apt nevertheless to picture the inside of the body, if not as pink satin, at least as beyond the range of reasonable scientific method. If, as I hope, there are a few engineers, physicists and chemists here, I would reassure them: physiology, and in particular that of the nervous system, is an experimental science like any other: no doubt it requires great experimental skill, but that makes it the more amusing: it is complex, but not beyond the wit of man to investigate: its complexity depends partly upon the difficult nature of its experimental unit, the single living cell, partly upon the fact that most of the effects which can be observed are due to the action and interaction of very many of these units.

The nerve fiber in which the waves run is part of a nerve cell: the central part of the nerve cell usually lies in or near the nervous system: the fiber—the axon—runs out to the organ, muscle, gland or sensory ending, with which it is connected. The fiber is a fine thread of protoplasm, a few thousandths to a few hundredths of a millimeter in diameter but often of considerable length. The velocity with which waves are propagated in these fibers may be anything from 100 meters to a few centimeters per second. In our own motor or sensory nerves the speed is somewhere near the upper of these limits.

The messages which pass in nerve fibers can be detected by various means apart from the response, *e.g.,* movement or sensation—which they provoke. The chief of these depends upon the fact that each impulse has an electrical accompaniment, which, owing to recent improvements in electrical technique, can be easily and accurately recorded. Not only, indeed, can we see nerve waves chasing each other along the screen of an oscillograph, not only can single impulses in single fibers be recorded photographically, but we can even listen on a loud speaker to sensory impulses caused, for example, by gentle pressure on the toe of a cat. As Adrian says, there would be no particular difficulty in demonstrating the potential change in a frog's nerve fiber as an audible signal on the radio. The power in the input circuit would be of the order of $10^{-14}$ watt, the transmitter might radiate 50 kilowatts, five million million million times as much. It would, as he adds, be a sad confession of failure if with these resources we had learned nothing fresh about the working of the nervous system. As a matter of fact, we have.

In, and in connection with, the living body itself as part of the complex telephone arrangements of the central nervous system, this electrical sign of nerve activity is the chief means by which in the last few years the subject has grown so fast. Other signs, however, there are, and the investigation of these has led to considerable advance in knowledge of the physical nature of the nerve wave itself. For example, when a single impulse travels down a medullated nerve there is an immediate rise of temperature of the order of $10^{-7}$° C. (one ten millionth of a degree). This represents a liberation of energy, small, indeed, but

perfectly definite, of about 4 ergs per gram of nerve. A single fiber one hundredth of a millimeter in diameter, if it weighed one gram, would need to stretch about 10 kilometers. Thus, in sending a single nerve impulse 10 kilometers, the amount of energy immediately set free would be about 4 ergs. One gram-calorie would send it $10^8$ kilometers, about half the distance to the sun. Clearly, communication by nerve fiber is not very expensive!

Let us remember, however, the number and variety of nerve waves involved even in ordinary activity. Nothing perhaps can better illustrate nervous action than a short discussion of the nature of muscular skill. What does a skilful muscular movement feel like to the performer himself: how does he control it as he proceeds: how does he learn it: how does he remember it: how does he reproduce it? We know that when any particular task is undertaken, any particular movement made, a stream of messages is sent out in appropriate sequence, most accurately adjusted, along tens of thousands of nerve fibers to the millions of muscle fibers that carry it out. We may imagine as a first and rough approximation that the brain and nervous system contain a carefully catalogued set of gramophone records, each ready to be taken out and turned on when required. If we come to a hurdle the high jump record is required: when we come to a ditch, the long jump record. In a sense this simple idea is true. Our behavior is largely composed of ready prepared gramophone records, called up and set going by the appropriate stimuli, and our skill in movement depends very largely on the degree to which we have learned to make it automatic. Nearly everything we do is partly unconscious. When we walk down the road we just give our nervous system general instructions to walk. We don't set out in detail how every muscle shall move, how every unevenness is to be overcome, we probably don't even know. Our movements, therefore, are largely automatic, they consist largely of gramophone records, prepared beforehand by instinct or by training and ready instantly to be turned on. On the number of the actions which we have learned to make automatic, on their coordination one with another, on the fineness and accuracy with which they are adjusted to the stimuli which evoke them, depend largely the skill and efficiency with which we work. True as this is, however, it represents only a very limited aspect of the truth, because it neglects one half of the nervous system, the half that tells us what we are doing and enables us to adjust it as we go, the half by which we really remember what muscular movement is like.

Take the simplest possible movement. Try to bend your finger slowly at a uniform constant speed. You will find that it does not really move uniformly but in a rapid series of jerks. A record may be made in some way, for example, by connecting your finger to a lever writing on a smoked drum, or by photographing a beam of light reflected from a little mirror stuck upon the knuckle. The record allows the jerks to be counted. If the jerks be few they will be large and the finger will seem shaky; if they be many they will be small and the finger will seem steady; the most skilful person, and the one with the steadiest hand, is he who checks and controls his movements most frequently and rapidly. In all our movements the mechanism "hunts" to find the right adjustment. The smaller the amplitude of the "hunting" the more skilful we are.

How is this done? From all the moving parts of the body, muscles, tendons and joints, a system of nerves runs inwards carrying information about what is happening in those moving parts. These messages are started off by end organs, excited by movements in the tissues where they lie. Muscles are ar-

ranged in pairs or groups, and any given movement is due to the cooperation or antagonism of a whole set of different muscles. When you sail a boat you don't just set the sails and tie up the rudder: you watch the wind, you adjust the sheet, you keep your hand upon the tiller, there is a continual interplay between the wind, the sea, the sails and the steering. In the case of bodily movement the nervous system is the steersman, who has to compound all the messages—the nerve waves—he receives to form one general impression on which to act. When a given muscle shortens, its antagonist has to lengthen. But notice: the antagonist does not let go all at once: if it did, the result would be like letting the sail out with a crash: it pays out gradually, in little jerks, each element in the contraction of one muscle provoking reflexly an element in the relaxation of its antagonist. This interplay is going on continually, one muscle hauling in a little, another paying out, so guiding and controlling the movement, keeping it as smooth, as accurate and as well coordinated as may be. This continual reaction between muscles, nerves, end-organs and central nervous system is the physiological basis of muscular skill, and on its smooth and efficient working depend many of the things that mankind finds worthy of accomplishment.

I will not venture inside the nervous system itself. That would require not a lecture but a series of lectures to discuss. You must think of the nervous system as a vast exchange, in which incoming messages from all corners of the body are sorted, assessed, correlated, recorded, in which the response most necessary in view of all the circumstances is worked out. The automatic telephone exchange, the control post of the automatic traffic signal, both carry out this function in respect of a single purpose: the central nervous system does it in respect of all possible purposes. I can do little more in this lecture than refer to the messages themselves, those which come in, those which go out, those which—in all probability—circulate within the exchange itself. These messages are all of one kind, and before we can begin to understand the nature of nervous action it is necessary that we should know something about the unit on which the whole of the mechanism is based, the wave which travels in the thread of living protoplasm.

The ending of every sensory nerve fiber has a specific kind of sensitivity, to touch, to pressure, to heat, to cold, to light, to vibration, as the case may be, and its manner of reacting also is specific. Certain properties, however, are common to all. Of these the most significant is the cycle of refractoriness and returning excitability which follow. All these organs are "relaxation oscillators" of the type I referred to earlier. The specific stimulus is the external cause or constraint which alters the level at which spontaneous discharge takes place: the stronger the stimulus, the lower the level, the more frequent the discharge. Some of these organs "adapt" to a constraint or stimulus. The hand put in warm water feels it warm, but in a very short time the organs sensitive to warmth adapt and no sensation is experienced. Similarly with touch. With sight there is some adaptation but not to the extent of complete lack of sensation: with the organs which tell us the state of tension in our tendons there is little: with sound there is practically none. The mechanism of this adaptation, this change of level of discharge, is not understood, but its existence is an essential part of our being. The level of discharge of some of our oscillators is not constant under a constraint but gradually rises; with these the frequency of discharge diminishes; with others the level remains constant for long periods and so the same frequency persists.

One limit to the nerve fiber and the wave that travels in it as a means of reporting to the nervous system events occurring outside is that it can not react (in the case of man) more than about 1,000 to 2,000 times per second and at that speed only for a short time. Two of the most important stimuli are those of light and sound: *light* waves have a frequency of the order of $10^{15}$, utterly beyond the frequency of the nerve fiber; to limit appreciation of *sound* below 1,000 to 2,000 waves per second would greatly interfere with its quality. Now if a single nerve fiber, with no specific properties, is stimulated at a frequency higher than it can follow, two things may result: (1) It may respond at the highest submultiple of the frequency which it can follow, *e.g.*, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$; (2) it may fail to respond at all. It will do the first if the frequency is not too high: the second if it is. It is well known that very high frequency stimuli (say 100,000/sec.) have no excitatory effect at all, even when of a strength many times greater than that of an ordinary alternating current. Sparks may be drawn from a man's hand with no more sensation than that of the heat produced by the current. This is commonly attributed to the fact that high frequency currents tend to travel on the surface of a conductor: the explanation will not hold, for two very good reasons: (1) the sensitive end organs are largely in the surface, so the effect should be greater, not less, and (2) with the high specific resistance of living material the skin effect is negligible, even at frequencies hundreds of times greater than those at which the excitatory effect disappears. The absence of stimulus is probably due to an electrical capacity existing at the surface of the excitable tissue, which prevents a potential difference from developing and a current from running across the surface until the capacity is charged. Whatever the explanation, the fact is a very obvious one: a nerve does not respond at all to stimuli of high frequency, which is probably why the limit of our hearing is about 30,000 waves per second. Below this limit, although an auditory nerve fiber is incapable of following say 10,000 vibrations per second, it can follow some submultiple of it, say 1,000 per second, and since the different fibers will very soon be out of phase with one another one tenth of them will respond to every cycle and the brain will in fact receive 10,000 volleys of waves per second. A number of nerve fibers can in this way respond to a frequency to which the individual fibers can not conceivably respond—a fact which has recently been verified by placing electrodes upon the auditory nerve and leading off to a loud speaker, when the ear and nerve together act as an efficient microphone, recording frequencies which no single fiber could conceivably follow.

In the case of light nothing of the kind occurs, nor presumably could it with electromagnetic waves except of very great wave-length, and no specific receptor for these exists. In the case of light a chemical reaction occurs between the physical factor—the electromagnetic vibration—and the response evoked by it. Unlike the case of sound, there is no direct numerical relation between the wave-length of the light and the response recorded. The stimulus is turned into chemical code in the retina, and forwarded by waves of various frequencies and in various fibers to the brain. There it is interpreted. The ear is capable of responding to frequencies from 50 to 20,000 or so, a ratio of 400 to 1, a matter of nearly 9 octaves. The eye responds only within one octave. The difference presumably is that the nervous mechanism is capable of transmitting the response to the separate sound waves as separate groups of conducted nerve waves to the brain; the light waves have to go by a roundabout way *via* a chemi-

cal reaction and a code. What a wonderful world of color we should have were our eyes sensitive to nine octaves!

One of the greatest achievements of physiology in the last years has been the proof by Adrian and his colleagues that the only way in which a sensory nerve fiber alters its response, as the strength of the stimulus is altered, is by a change in the frequency of the waves which it forwards to the central nervous system. I may have disguised my meaning by a too careful choice of words, but I fear the wrath of my psychological friends if I dare to hint that the sensation due to a stimulus is measured by the frequency of the nerve waves which it produces. The total effect of a stimulus depends upon three factors: the number of fibers which, by means of their end organs, it affects: the frequency of the waves evoked in each of these fibers: and the state of the nervous system, as affected by other stimuli simultaneously occurring, and other such factors. If I am to keep outside the central nervous system I must never come to sensation at all, but refer only to the number of separate nerve units reacting to a stimulus and to the frequency of the reaction of each. The waves in these fibers are, however, at least the physiological basis of sensation.

At the other end of the scale is the response of muscles and glands by which the purposive reactions of the nervous system are effected. Here again waves in nerve fibers are the means by which communication is effected and orders despatched. These are waves of the same identical nature as occur on the sensory side, but waves of the type occurring in nervous conduction can never cross one another, one-way traffic is necessary, and separate motor nerve fibers are provided. Here let me make a digression for a moment. A wave leaves a discharged region, a refractory region, behind it; for the same reason as waves can not follow one another with less than a certain interval two waves can not cross—each comes into the discharged region of the other and both are wiped out. Curiously enough, however, all tissues capable of conducting these waves are in fact able to do so equally in either direction: though in normal life, except in special instances (and perhaps in the central nervous system itself) they never do. Sometimes tissues are so arranged that a wave can take on a circus movement and go on running round—chasing its own tail—more or less indefinitely: this curious phenomenon, discovered in the heart of a marine animal, is the basis of an important clinical disorder of the human heart. In the nerve networks of some primitive animals, and in those of the vegetative organs of higher ones, the same type of circus movement of nerve waves probably occurs. Mainly, however, one finds waves which begin and end in a single stretch of conducting tissue.

These waves, which are orders to the effector organs, reach in general three types of reacting cells—voluntary muscle cells, involuntary muscle cells and gland cells. Their passage to the voluntary muscle cells is so rapid that one tends to regard it as of the same nature as conduction in the nerve itself. In the other two it may have as intermediary, at least in certain instances, the liberation of a chemical substance—*e.g.*, acetyl choline or adrenaline—which slowly produces a more prolonged response. The manner and mechanism of conduction from nerve to muscle fiber is still disputed, but there are some interesting facts to record.

Let me first, however, refer to muscle and its response. The elementary unit of muscular contraction is the twitch—a rapid wave of shortening—lasting only a few hundredths of a second in a human voluntary muscle. All ordinary contractions are made up by the fusion of such twitches: and the strength of a

contraction depends upon the number of fiber groups reacting and the frequency with which these react. A maximum effect is made with 50 motor impulses per second. This frequency can, as a matter of fact, be rather easily seen in a muscle by recording either its mechanical or its electrical response in a strong contraction. In a weak contraction the fibers are reacting at a lower frequency and out of phase with one another, so not much is seen. In a strong contraction groups of them seem to fall into phase by some kind of resonance in the central nervous system. Normally the impulses pass from nerve to muscle without hindrance. In some conditions, however, a block is interposed across which the waves can pass only with difficulty, if at all.

Such a condition may exist in a normal muscle after severe fatigue: experimentally it is best seen by poisoning with the South American arrow poison, curare. In this state the first effect is that only low frequency impulses can be transferred from nerve to muscle: the next is that complete paralysis occurs. The mechanism of this paralysis is disputed, but one curious and interesting example of its occurs in man. A disease exists called *myasthenia gravis,* in which the patient is incapable, for more than a second or two, of making any considerable effort. If the ulnar nerve in the human arm be stimulated with a series of electric shocks the muscles working the fingers are thrown into contraction. In a patient with myasthenia two things may happen. If the shocks are of rather high frequency the response rapidly fades away. If they are of low frequency the response is nearly normal. When failure to respond to a higher frequency has occurred, transfer to a lower frequency gives the full response again. Here apparently there is an abnormal condition in nerve or nerve-ending which is probably the cause of the characteristic sign of the disease. Few physiologists are so sour that such a sudden contact with clinical medicine does not give them a thrill of pleasure. Such contacts, seemingly by chance, provide even the most academic science with its relation to reality.

Apart from the ordinary motor and sensory impulses to which I have referred, a multiplicity of mechanisms exists all over the body, depending on the use of impulses in nerve fibers for coordinating function. The lungs, for example, expand and contract rhythmically. This depends partly upon a genuine rhythmic function in the center—a spontaneous discharge of waves from certain cells. On this, however, a major control is exerted by impulses sent from end organs in the lungs themselves. The movement of the lungs excites these organs which discharge waves along fibers to the center and so check and control and limit the contraction of the diaphragm. Normal breathing is a balanced movement consisting of the continual interplay and adjustment of impulses going to and from the center. Another such mechanism exists in the carotid sinus by which the pressure and composition of the blood cause impulses to be discharged to the centers by which adjustments of these are effected. With the high power of modern electrical instruments there is scarcely any corner of the body from which such messages can not be found pouring out—and listened to with loud speakers, recorded with oscillographs.

You probably have heard the story of the little boy who wanted to know how animals came into existence and had been told by his mother that God had made them. "And did God make flies, too, Mummy?" "Yes, dear." "A fiddling job making flies." If he could have connected loud speakers and oscillographs on to the nerve cells and nerve fibers of a fly and heard and seen the

amazing complex of wave motion, roaring backwards and forwards even in that small creature, he would have realized that "fiddling" was far too mild an adjective. I do not know how many motor and sensory medullated nerve fibers there are in a man, but let us guess. Assume that they weigh altogether 100 grams, that they have an average length of 50 cm and an average diameter of 14 $\mu$. This would give about a million of them: I expect this is an underestimate. Let us think of a man running in a quarter mile race, exerting himself to his utmost. I think we may admit an average of at least 10 impulses per second to each of the fibers; total, 10 million waves per second. This hurricane of coordinated impulses is raging in our runner. Even at rest I suppose we may allow him one twentieth of this, half a million per second. Each of these impulses could be picked up and recorded or made audible by modern electrical technique. Each wave has the same general characteristics. Each is a reasonable and intelligible thing. The properties of a gas depend upon the average behavior of its molecules, but that is governed by statistical rules. The properties of a man depend upon the total behavior of his nerve impulses—but these—although so many—are coordinated and adjusted. Truly, as David said, we are fearfully and wonderfully made.

# PLANT PATHOLOGY AND THE CONSUMER

By Dr. NEIL E. STEVENS

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Now that "Mankind at the Cross Roads" and the various less thoughtful tracts which threatened us with early starvation have passed into the shadow of the greatest food surplus of modern times, it is no longer possible for the plant physiologist or pathologist to justify his activities on the simple grounds of the necessity of saving the human race from hunger. This may then prove a favorable time for a reexamination of the practical results of plant disease control measures in this country during recent decades. At present there is a tendency for the plant pathologist to apologize for his profession. His apologies cover, of course, only the practical phases of his work and not the fundamental investigations, the results of which form international assets and which in our day need neither justification or apology. Obviously, if all the professional plant pathologist has to offer as a practical reason for existence is still further expansion of production, he is entitled to a prolonged holiday, and unless he can demonstrate the contrary he will probably get one.

It may be conceded freely at the outset that it is a general conception that the chief aim of applied plant pathology is the production of larger crops and that the benefits of plant disease control go to the producer of food rather than to the consumer. A somewhat more careful examination of the work of the plant pathologist shows that he is fully as much concerned with quality as with quantity of product and that the practical results of his studies are in many cases of even more benefit to the consumer than to the producer. The popular misconception referred to above is due in part, of course, to the great interest in foodstuffs taken by the agricultural population and the very great ignorance regarding the food supply common among city dwellers. It is also partly due to ill-advised propaganda.

It would be easy to demonstrate that, in general, technical improvements in agriculture which increase production actually redound chiefly to the benefit of the consumer. This point of view is adequately summarized in the report of the Secretary of Agriculture for 1931 (p. 25):

> Technical progress has increased farm productivity tremendously in the last 15 years, but the benefit has gone largely to the consumers. Farming has been industrialized and mechanized. It has used science, decreased its production costs, and increased its output, without finding either profit or security in the process. It has made two blades of grass grow where one grew before, only to find the second blade depressing the price of both.

The purpose of the present paper is not to discuss this general proposition but to point out a few of the specific ways in which the results of plant disease studies have been of benefit to the consumer, have indeed functioned directly as "consumer's research," if I may borrow the name of an active and worth-while modern organization.

### Timber Treatment

Direct benefit to consumers from the investigations of plant pathologists is illustrated in the success of preservative treatments in prolonging the life of timber used out-of-doors. Methods of treatment as well as types of preservatives have been improved in recent years, but even those available twenty years ago were of measurable benefit.

Fig. 1, taken from the report of the twenty-eighth annual meeting of the

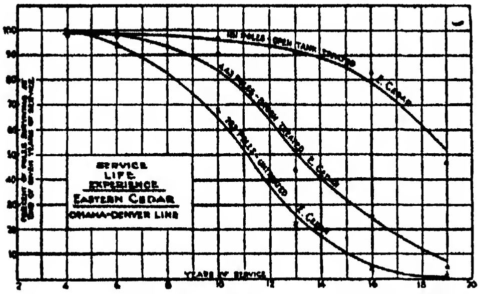


FIG. 1. SERVICE LIFE EXPERIENCE OF TREATED AND UNTREATED TELEPHONE POLES ON OMAHA-DENVER LINE.

American Wood-Preservers' Association, shows the results of actual experience under field conditions with untreated telephone poles as contrasted with those treated by two different methods. It will be noted that at the end of 19 years practically all the untreated poles had been replaced, while half of those having the best treatment were still in service.

Something has been accomplished in the study of the diseases of growing trees and the control of certain forest nursery diseases, but no progress in this field has yet been observed which is at all comparable to this achievement of doubling the useful life of poles. In considering these results it should not be forgotten that, measured either in terms of human labor or dollars, the telegraph pole or railroad tie ready for use is a much more costly article than the growing tree. The situation is well summed up by Colley:[1]

> To the consumer, decay in forest products means more than the loss of the actual wood which has become rotten. It means replacement costs for lumber and labor, idle factory space and abortive attempts to use substitute materials in places where nothing can ever have the utility of wood. The individual purchaser bears most of the expense.

[1] *Science*, 61: 107–109. 1925.

While the benefits from modern timber treatment are most readily available to large organizations which can treat their own material, it is already possible for the individual householder in certain parts of the country to purchase small lots of treated lumber, and the supply will increase as demand grows.

## THE PROBLEM OF DECAY OF FRUITS AND VEGETABLES IN TRANSIT

The losses from decay of fruits and vegetables in transit and on the market fall directly on the food consumer, although like many of his other taxes he pays them unconsciously. The price which the consumer pays must in the long run cover the losses of transportation and sales agents. Any reduction in such losses is a direct gain. Losses in "perishables" have been notoriously high and very difficult to reduce. This is well shown by recent reports of the freight claim division of the American Railway Association, a unit especially charged with the task of reducing the cost of "loss and damage" in railway shipments. The subjoined table, for which I am indebted to Mr. Lewis Pilcher, secretary of this division, shows both the high degree of success attained in reducing "loss and damage" in all

TABLE I

ANNUAL "LOSS AND DAMAGE," AS REPORTED BY FREIGHT CLAIM DIVISION OF AMERICAN RAILWAY ASSOCIATION

| Year | All commodities | Fruits, melons and vegetables (only) |
|---|---|---|
| 1921 ........ | $96,730,376 | $13,898,081 |
| 1922 ........ | 48,084,995 | 8,830,192 |
| 1923 ........ | 49,540,377 | 10,098,402 |
| 1924 ........ | 48,262,543 | 12,058,608 |
| 1925 ........ | 38,772,097 | 8,851,871 |
| 1926 ........ | 38,187,315 | 8,298,529 |
| 1927 ........ | 38,713,059 | 9,207,554 |
| 1928 ........ | 36,557,243 | 9,406,578 |
| 1929 ........ | 37,432,966 | 10,366,134 |
| 1930 ........ | 36,239,640 | 11,792,569 |
| 1931 ........ | 25,868,485 | 9,150,161 |

commodities and the relatively great difficulty of affecting that portion which includes fruits, melons and vegetables.

The reduction in the total from over 96 million in 1921 or even 48 million in 1922 has been marked and on the whole continuous. The amount so paid in 1931 was less than 26 million. The loss from perishables, on the other hand, was higher during the period 1929 to 1931, inclusive, than in the preceding triennium or even from 1921 to 1924. During the first five years, 1921 to 1925, the cost of "loss and damage" from fruits, melons and vegetables constituted approximately 19 per cent. of the total. During the five years, 1927 to 1931, it made up over 28 per cent. of all "loss and damage." In spite of this somewhat discouraging showing, something has been accomplished in those lines where most work has been done.

### Reduction of Losses to Tomatoes and Strawberries in Transit 1922 to 1930

Both tomatoes and strawberries have long been recognized as being very subject to decay in transit and on the market, and although the field diseases of the two crops are different, the decays which occur in transit are in some ways comparable. An important part of the loss in each crop is due to a species of Rhizopus, which enters through wounds and produces the characteristic decay usually known as "leak."

Recent summaries of losses in transit, compiled from the reports of the food products inspection service of the Bureau of Agricultural Economics, make possible a rough comparison of the losses due to decay in transit from certain Southern states having long hauls to market. These reports are based solely on market inspections by unprejudiced observers and, therefore, furnish a type of information not obtainable from the usual sources of plant-disease reports or crop-loss estimates.

The figures for both tomatoes and strawberries deal with those producing states having the largest number of market inspection certificates. In the case of strawberries the certificates studied included shipments from Alabama, Arkansas, Delaware, Florida, Kentucky, Louisiana, Maryland, Missouri, North Carolina, Tennessee and Virginia. These eleven states had in 1930 over 113,000 acres of strawberries, which represented almost two thirds of the "commercial" strawberry acreage of the country. Figures for tomatoes are based on inspection certificates from California, Florida, Mississippi, Tennessee, Texas and Mexico. The five states considered, namely, California, Florida, Mississippi, Tennessee and Texas, had in 1930 somewhat over 109,000 acres of tomatoes grown for the fresh fruit market. This represents about two thirds of the commercial acreage reported as grown for the fresh market in the United States.

Using as a measure of loss what Dr. D. H. Rose has called "a disease index," namely, the sum of the percentages of all the diseases noted, and comparing the four-year period 1923 to 1926 with the four-year period 1927 to 1930, it is evident that there has been a reduction

TABLE II

Comparative Losses in Transit of Tomatoes and Strawberries from Certain Southern States as Indicated by Inspection Certificates

| Year | Losses in transit Tomatoes | Strawberries |
|---|---|---|
| 1922 | 12.8 | 8.6 |
| 1923 | 11.7 | 9.0 |
| 1924 | 9.5 | 5.2 |
| 1925 | 9.1 | 4.2 |
| 1926 | 9.8 | 4.3 |
| 1927 | 8.9 | 4.1 |
| 1928 | 8.1 | 3.0 |
| 1929 | 7.2 | 4.6 |
| 1930 | 7.7 | 3.4 |
| 1923–1926 | 10.0 | 5.7 |
| 1927–1930 | 8.0 | 3.8 |

of losses during the latter period in both these crops.

If these percentages look small, it should be remembered that the annual commercial strawberry crop of the United States varies from 200,000,000 to 300,000,000 quarts, and the commercial crop of tomatoes usually runs well over a million tons. Among the factors which may account for this difference, improved handling methods and improved refrigeration seem to be the most probable. There have been few changes in varieties or in cultural methods, but much educational work has been done which has tended to improve handling methods, and there have been mechanical improvements in refrigeration and equipment.

Such gain as has been made in tomatoes and strawberries has come through the gradual improvement of handling and refrigeration directed toward the control of certain rot fungi, and the figures here given are derived from a number of widely separated producing areas. More striking results are shown where direct control methods have been applied in areas of intensive cultivation of a single crop. As an example of a specific disease control measure which has become part of regular commercial practise to the advantage of the consumer, the control of apple scald may be cited.

### Apple Scald

Scald has long been recognized as a serious disease of apples during the latter half of the storage season. The disease was made the subject of much study, and finally there was developed a simple and easily applied control method—that of packing box apples in oiled wraps and barrel apples in shredded oiled paper.

The results of this treatment in apples shipped from the state of Washington are graphically shown in Fig. 2, compiled from the inspection certificates

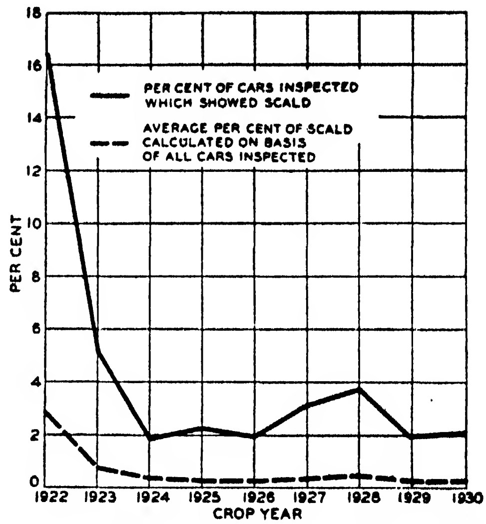


Fig. 2. Amount of scald in boxed apples from the state of Washington as shown by the inspection certificates of the Food Products Inspection Service.

of the food products inspection service, Bureau of Agricultural Economics, U. S. Department of Agriculture. A small proportion of the Washington apple crop was packed in oiled wraps in 1922, a much larger amount in 1923, and by 1924 the method had been generally adopted. Since that time it has continued in popularity and has become a part of regular commercial practice in that region. In 1922, a year in no way exceptional in the incidence of scald, the percentage of inspected cars showing scald was 16.4. This fell to 5.3 in 1923, and in the succeeding years has averaged approximately 2.5, which is somewhat less than one sixth of the amount for 1922.

### Plant Pathology and the Ultimate Consumer

For those whose ideas of "consumer" is even to-day restricted to the "ultimate consumer" who actually eats the food, wears out the floor boards or talks through a telephone, as well as for those

who are not ready to concede that under present conditions reductions in production costs reach such ultimate consumers, it may be worth while to point out that many losses, preventable or reducible by methods developed by plant pathologists, fall largely and inevitably on this very ultimate consumer. The fact that the plant pathology of the kitchen has been little discussed or emphasized has, perhaps, obscured the fact that here are met many of the most serious losses from plant diseases. It must be obvious that for a given percentage of loss by disease in fruits and vegetables the consumer's loss is actually greater than the producer's for the simple reason that the individual unit is so much more expensive. That is, the consumer's apple is the producer's apple plus the cost of picking, packing, shipping, storage and handling, as well as sales costs and profits.

In addition to this it should be noted that the actual percentage of loss in the home is often much larger than the losses usually recorded either in field or in transit. This is especially true of decays of fruits and vegetables. A conspicuous example of this is the apple scald discussed above. Serious as the losses appeared to be to those who produced or stored apples they were relatively much more serious to the housewife who in peeling a badly scalded apple for cooking or eating threw away one fourth to one third of the otherwise edible portion.

The same thing is true for such preventable diseases as potato scab, which apparently does not affect the vigor of the growing plant or the total yield and may well pass for a mere surface blemish to unsuspecting housewives but results in a real loss in the quantity of food available to the (in this case the literally) ultimate *consumer*. This relation holds, even more strikingly, for decays of the more perishable fruits. For example, a loss of 10 per cent. in a car of strawberries would be considered very large, indeed, but in a fairly large proportion of boxes of strawberries the purchaser finds it necessary to throw away more than 10 per cent.

It was admitted in the opening paragraphs that neither the professional plant pathologist nor the consumer ordinarily realizes that the practical benefits of plant disease studies go in large measure to the ultimate consumer. This failure to recognize the closeness of the relation has, of course, no bearing on its reality, but may well hinder its fullest development. Somewhere in his collected legal papers Justice Holmes develops the philosophy that men may well do most for the public good under "the illusion of self-seeking." He insists further that, "We all, whether we know it or not, are fighting to make the kind of a world that we should like." My own feeling is that the plant pathologists of this country are working, whether they know it or not, largely in the interest of the consumer. And further, that it would promote better relations all around and more effective progress if the fact were generally understood.

# CAUSALITY IN THE PHYSICAL WORLD

By Professor R. B. LINDSAY

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HUMAN life is proverbially uncertain; it is commonly said that in this world we are sure of nothing but death and taxes (one might almost say further, an increase in taxes). In sharp contrast, the inorganic universe in which we live and which is the object of our senses has been commonly assumed by most to be governed in all its workings by quite definite and immutable laws which, like those of the Medes and the Persians, "altereth not." No matter how disorderly mere man shows himself, the large scale universe at least is on the side of law and order. The actions of a politician may be decidedly unpredictable, but for nature the great principle that every effect has a definite cause seems to be still on the job. At least this has been the common feeling up to rather recent times. In the past few years, however, there have been some very disturbing reports from the laboratories and the studies of physical scientists. The mystic but somewhat discouraging word "probability" begins to be heard more and more frequently; more and more frequently the Sunday supplement cartoonists are called upon to produce pictures of chaos to illustrate the popular accounts of the latest developments in theoretical physics. We learn that the greatest authorities are convinced that the watchword of nature is no longer "cause" but "chance," and more disturbingly still, not merely the kind of chance which the life insurance company exploits to the advantage of all its policy-holders, but also the kind of chance that is displayed in the speculations of the stock market. We are presumably asked to adopt the view that nature is in the last analysis the plaything of a gambler, that nothing in the universe is really predictable.

Now the question which I wish to discuss in the present article is simply this: What is the justification for this new view? Is the situation after all as serious as it sounds? And is it not possible that the popular accounts may be leading to an unfortunate misunderstanding of the whole problem? Of course one who desired to be only moderately cynical might say at once that all attempts to popularize science lead to misunderstanding, and hence that my attempt will probably merely lead to "confusion worse confounded." I can only hope that this result, to use the new jargon, will not follow with certainty but merely with a certain degree of probability.

Before one can have any appreciation of the meaning of causality in physics, it is necessary that one shall understand just what the physical scientist does, what his business is. It may be objected that this is a long story. That is true, but a brief survey seems essential. To state what science (or, in particular, physical science) is in words of one syllable is, of course, not easy. As an introduction consider the following, a slight modification of a parable of the philosopher Schopenhauer: "Two Chinamen traveling in Europe went to the theater for the first time. One of them did nothing but study the stage machinery, and he succeeded in finding out how it was worked. The other tried to get at the meaning of the play in spite of his ignorance of the language. In the former you have the physical scientist, in the latter the philosopher." This is not intended to be at all derogatory to the philosophers. But no one can fail to

see the profound difference in method that is here implied. Both philosopher and scientist seek for an understanding of the experience of mankind, *i.e.*, the sum total of our sense-impressions of all kinds; but while the philosopher (at any rate in the past) has sought to appreciate experience as a whole in what may be called its fundamental aspects, the physical scientist tries to abstract from the totality of experience certain small sections which he thinks he has some hope of describing in such detail that the result holds meaning for himself and other persons with similar interests. It is commonly said that the task of science is to explain all natural phenomena, but it is well to recognize that the scientist here uses the word explanation in a very special sense, namely, that better expressed by the term description. It is not the function of the physicist to answer the question why experience is as it is, but rather how do things actually go. The latter is a less ambitious program than the former. Perhaps that is why it has proved so much more successful during the three or four hundred years during which it has been pursued. Many well-intentioned and enthusiastic people have indeed attempted, for example, to explain why the law of gravitation holds, that is, why every particle in the universe should attract every other one with a force inversely proportional to the square of the distance between them. They have done this by the invocation of all kinds of cosmic urges and mystical forces. However, it is safe to say that all this has proved worthless for the development of physical science as compared with the simple assumption of Newton, expressed in mathematical form. For the latter, when combined with the principles of mechanics, has yielded the whole of celestial mechanics, one of the crowning achievements of the human mind. Of course, I must hasten to add that there have been theories of gravitation, some of which, like that of relativity, will undoubtedly prove of significance for physics. These, however, are in quite a different category from "crank" literature, as a close study of the meaning of a physical theory will show.

If, then, the task of the physical scientist is to construct a description of certain limited portions of experience, we ought to say a few words about the character of this description, the method by which it is made. In the first place, we must note that the data of physical science are obtained almost exclusively from experiment or controlled sense-perception. Passive observation, stimulated by idle curiosity, may have been good enough for ancient times but has long since ceased to suffice: the physicist now insists on abstracting from the totality of experience a small domain for specially intensive investigation; he has in his mind certain ideas which relate to this domain and which lead him to frame definite questions; finally he decides to go through a well-defined course of activity by performing some carefully thought-out operations in the laboratory. This operational idea is closely connected with the notion of measurement. It is here that there enters into science the highly sophisticated mode of thought called mathematics with its attendant symbolism, of which number is the most important form. Every experiment in physical science in which measurement plays a rôle (and these are in the overwhelming majority) reduces essentially to an operation involving the observation of the coincidence of a point or pointer with a mark on some scale, or the comparison of sets of such coincidences; the symbolic expression of the observation is made by means of numbers associated with the marks. We think at once of such illustrations as measurement of temperature with a thermometer, of electric current and electromotive force by means of meters, of mass by a balance, or time by a clock,

etc., etc. In every case there is a scale and in every instance we are interested in the position of a pointer on that scale: the result we insert in our note-book is a number representing the position of the pointer on the scale or what Eddington has called a pointer-reading, a now justifiably famous term.

The brevity of these remarks is, I fear, rather disconcerting, but at any rate it is evident that some rather fundamental matters are involved. The use of scales and a clock at once introduce the notions of space and time and commit the physicist to some kind of view with regard to these categories. More important still, perhaps, is the emphasis on the fact that the description of physical experiments is carried out in terms of number symbolism. This is an extremely significant state of affairs. Its adoption has colored the whole development of physics, so that now physics without the symbolism of mathematics appears meaningless. Of course the symbolic method has far transcended the elementary use of numbers. There is hardly a branch of mathematical symbolism which has not found valued use in physics. But this is too deep a subject for us to sojourn longer.

We must return to our physicist and his description of experience. From the results of his experiments he seeks to frame laws which are brief, symbolic expressions describing certain apparent routines of experience. To call laws like those of Boyle, Ohm, Hooke, etc., to mention but a few of those familiar to every student of elementary physics, mere shorthand descriptions of actual laboratory operations is, however, to do injustice to their true significance. Rather the real value of a law is that it represents confidence in the possible repetition of a certain set of operations. The physicist, for example, after numerous experiments writes the equation $PV = K$, where P is the symbol for an operation which he calls measuring the pressure of a gas (and by which operation a number may be attached to P), V is the symbol for a corresponding operation called measuring the volume of the gas, and K is a constant as long as the temperature is constant. There is very little meaning or value in this expression if it is a description of merely one operation conducted at one particular place at one particular time. Its significance consists in the fact that it describes more or less faithfully a multitude of similar operations, irrespective of time or place. It contains within itself the power of prediction of the future, for it tells us, if at any future time we carry out a certain prescribed set of operations, just what we may expect to happen. It expresses our trust in a certain consistency of nature.

Now it is important to realize that this confidence in the consistency of nature is never justified in actual fact. No experiment ever gives precisely the result predicted by the law or laws which purport to describe it, and at times the discrepancy is very considerable. This, however, does not discourage the physicist, who is by nature an optimist. We must remember that though his business is to describe the world of experience, he does it by constructing a world all his own. This is what we may call the physical world. It should be called the physicist's world. It is the world where the physicist's laws never go wrong and never fail in their prognostications. I suppose we may say that it is his idea of heaven.

To say that the physical world is a world of symbolic laws is not enough. It is a world of theories, those conceptual generalizations from which all the laws descriptive of a certain group of phenomena may be deduced by purely mathematical means. Thus we have the theory of mechanics, one of the grandest generalizations ever created by the mind of man, and the concomitant mechanical theories of light, sound and heat. In

the building of each theory the physicist begins with certain concepts suggested by experience and defined in terms of actual or conceived operations through the use of naïve psychological notions. Such are, for example, the concepts of velocity, acceleration, mass and force in mechanics. These concepts are all expressed symbolically and certain mathematical relations are assumed to hold among them. In classical physics these are usually in the form of differential equations and constitute the fundamental hypotheses of the theory. From these hypotheses and the basic concepts deductions may be drawn by purely mathematical means. These deductions are themselves mathematical relations among the symbols. If they agree with the physical laws descriptive of phenomena in some field, the physicist says that he has a physical theory of these phenomena. Naturally the aim always is to make the theory subsume as large a group of phenomena as possible, and our satisfaction with a theory varies in accordance with its domain of validity. This, however, is not all. We want a theory to be able to predict new laws which will be verified by further experimental investigation. Close examination shows, indeed, that precisely this ability to predict is the real criterion for the success of every physical theory. When Maxwell, for example, predicted the laws of electromagnetic wave propagation from the electromagnetic theory he had built on the work of Faraday, he secured for the theory a much more wholehearted acceptance than would have been possible on the basis of the success with which the theory described phenomena already known.

We are now ready to see where causality fits into this picture. We have already noted that the physical world is a world of concepts, laws and theories, and in that world the physicist has complete control. What meaning does causality have for him? It must be confessed at once that the popular notion of cause and effect has little significance in his eyes. This notion expresses the tendency to separate every physical phenomenon into two parts, of which the first is said to be the cause of the second and the second the effect of the first. Consider as a simple illustration the extension of a wire by a weight, described symbolically by Hooke's law. The weight or at any rate the act of attaching it to the wire has been popularly called the cause of the extension, while the extension then figures as the effect of the weight, the idea being that with the force or weight in operation the extension takes place, while without it the extension does not take place. There may be a certain advantage in this popular version, and certainly it is an instinctive stand taken in every-day life. However, it has little value in the physical world. In the example cited, the physical law states a relation among symbols which represent well-defined laboratory operations, and there is no notion of precedence or antecedence involved in them. If this is the case, just what does causality signify? It means assigning universal and everlasting validity to every physical law. This implies in turn the possibility of the exact prediction of the future state of any physical system as soon as we know its state at any instant. The classical illustration of causality is drawn from mechanics. There are certain laws which purport to describe the motion of a planet about the sun. These are such that if we know the position and velocity of the planet at any instant we can calculate its position and velocity at any subsequent instant or indeed at any instant in the past. In other words, we may look upon the whole future and past of the mechanical system in question as strictly determined from its state at a given instant. In this sense causality is equivalent to determinism. The success that celestial mechanics has encountered in predicting actually ob-

served celestial phenomena like eclipses has of course gone far to emphasize the power of the causality principle as it is employed in classical mechanics. Nevertheless, it must again be borne in mind that, though strict determinism holds in the mechanics of the physical world, there is still no complete assurance that such will be found to be the case in the world of experience. The physical theory may make a prediction, but all we can say is that there is more or less probability of the prediction being verified. In many cases, such as that of the prediction of celestial phenomena, numerous trials have made us feel that the probability of verification is overwhelming, but even here we never expect to get exactly the result theoretically predicted. Even eclipses are apt to be a few seconds off. What conclusion shall we draw? Simply this—that though causality in the sense of exact determinism is a basic principle of the physical world, it does not hold in the world of experience. Does this mean that we live in a world of blind chance? We find it hard to believe that, and so we dilute the definition of causality somewhat by the admixture of a little probability. Most practical people do not object to this, and it certainly bolsters up our confidence in the utility of science. To be sure, there are some scientists who prefer to go the whole way and, because complete causality is impossible, become outright indeterminists with the thesis that all physical laws in their application to the world of experience have only statistical validity, that is, they work on the average; deviations and fluctuations must, however, be expected.

Now I do not wish to give the impression that the principle of causality has been universally employed, even in the construction of the physical world. Consider, for example, the kinetic theory of gases, according to which a gas is assumed to consist of a large number of small particles called molecules moving in straight lines in every direction with varying velocities and colliding frequently with the walls of the confining vessel and to some extent with each other. It is further postulated, at least in the simplest presentations of the theory, that each molecule is a rigid sphere and that its motions are to be described by the ordinary laws of collisions in classical mechanics (*i.e.*, conservation of momentum, etc.). This is of course a construction in the physical world and in particular one based fundamentally on classical mechanics. From this point of view the problem of the description of the large scale properties of a gas would reduce to the ability to calculate the position and velocity of every molecule at some definite instant of time. The number of molecules, however, is so great that this is a hopeless task. What do we do in such a quandary? We invariably fall back on statistical considerations. We cease altogether to fix attention on the individual members of the aggregate and concentrate on the average. This involves a theoretical departure from strict causality that we make cheerfully for the sake of convenience; and, of course, it is well known that the statistical theory of gases and more recently of liquids and solids as well has proved of enormous utility. I cite this illustration in order to stress the fact that the physicist does not always feel himself bound to use causal laws in the construction of the physical world. It is worth while to emphasize that, even in the development of classical physics, probability considerations have been used repeatedly, and no one has raised any hue or cry about it. The question then arises: What is the meaning of the present flare-up of anxiety?

The reason is to be found in the new quantum mechanics theory of atomic structure and in particular in the now famous principle of uncertainty or indeterminism of Heisenberg. This prin-

ciple is interesting because it purports to fix limits to the exactness with which measurements may be carried out even ideally. The now classic example is that of the electron. Suppose we wish to measure its position with great precision. It is then asserted that we must sacrifice precision in measuring its velocity; we must remain content merely with the probable value of the latter, or with the probability that the electron shall have a velocity lying in some assigned interval. More precisely still, if we denote by x and v the position coordinate and velocity of the particle, respectively, by $\Delta x$ the limit of accuracy to which x can be measured (*i.e.*, the possible error in fixing x) and by $\Delta v$ the corresponding limit for velocity, the principle may be expressed symbolically in the form

$$\Delta x \cdot \Delta v \geqq h/m$$

where h is the so-called Planck constant of action, of magnitude $6.55 \times 10^{-27}$ erg sec, and m is the mass of the particle. According to the principle the product $\Delta x \cdot \Delta v$ is at least as great as h/m, though it is to be observed that the actual magnitude is not stated, the implication being that the order of magnitude of the product is that of h/m. It is clear that for particles of ordinary mass, the uncertainty predicted by the principle is negligible. However, this is by no means the case for a particle like an electron, whose mass in grams is numerically comparable with h. In this case, if $\Delta v$ is very small, $\Delta x$ may be relatively enormous, indicating complete inability to localize the electron if the velocity measurement is to be precise, and *vice versa*. The net result of the principle is thus frankly acausal or indeterministic. For, if we can not fix both position and velocity of an electron at any instant, we certainly can not fix its state at any subsequent time. We have lost our power of prediction with respect to it.

I should like to point out that in the form in which this principle is stated here, it is a deduction from rather specialized assumptions in quantum mechanics, rather than a definite result of the general postulates of that theory. It is indeed true that from the latter may be derived a theorem which, when translated into language involving our usual notions of space and time, is most naturally interpreted in the above fashion. However, it is only fair to add that this interpretation is one which assigns a meaning to such a thing as the measurement of an electron. It is perfectly possible to take the stand that such a measurement is really meaningless. This of course would entail the result that our physical world picture of such an entity as an electron as existing in space and time has broken down. Does this mean that the causality principle has gone into the discard? Not at all! It is true that if we wish, on the theory of quantum mechanics, to continue to think of electrons which can be localized in space and time we must sacrifice determinism. However, the theory of quantum mechanics does not force us to think of electrons in this way. It provides a perfectly satisfactory way of looking on the problems of atomic structure without invoking our usual space-time picture, and this way is certainly purely deterministic or causal in the usual physical sense. It is only when we try to translate the results of this theory into our usual space-time language that the failure of causality becomes evident. It is clear that in using our ordinary space-time concepts too closely in building the physical world we have been hampering ourselves unduly. Quantum mechanics shows the way to emancipation. It is a difficult way mathematically and there are probably not many except theoretical physicists who will care to try to follow it. This, however, is not important. What is important is that there is no

real breakdown of the principle of causality involved in quantum mechanics. Precisely as in classical mechanics, the difficulty occurs when we try to make the transition from the physical world picture of quantum mechanics to the world of experience.

There has been considerable speculation concerning our inability to construct a physical theory of atomic phenomena, using our classical notions of space and time, without running into indeterminism. Much has been made, for example, of the fact that all physical measurement is based on the possibility of observing a phenomenon without disturbing it. In order to measure anything we must go through certain operations. These imply the activity of an observer, whether he is on the spot in person or not. This is pretty obvious in the case of most laboratory operations, but it is well to emphasize the fact that even the act of looking through a telescope at a star in order to observe its position really disturbs the star. Of course in this and many other cases the disturbance is so monstrously small that we think little about it. On the other hand, it is conceivable that experiments in atomic physics are much more seriously affected by such disturbances. Thus to quote a commonly used example, if one wishes to locate an electron one must "see" it, and in order to see it, one must illuminate it. But the very act of illuminating it disturbs the electron so much that it is in an altogether different state after illumination than before, and examination indicates that the shorter the wave-length of the light (*i.e.*, the more sharply defined the electron), the more disturbance will the electron suffer. Indeed it is possible to give a kind of deduction of the uncertainty principle from an analysis of an experiment of this kind. It is possible to take the attitude that if there were no observer at all the electron would have its behavior completely determined. The lack of determinism on this view arises solely from the unfortunate presence of the observer. There are at least two possible solutions. In the first place one may absorb the observer (*i.e.*, the subject) and the thing observed (*i.e.*, the object) into one single system in which strict causality will reign, though of what earthly use it will be it is hard to see on the basis of our present view of the descriptive nature of physical science. On the other hand, it is possible to take the stand that man and his instruments are too closely a part of nature to be sufficiently objective in the description of experience, but that it is possible to imagine an ideal mind capable of observing and describing with no disturbance and with complete objectivity all that ever happens in the universe. This last idea has been suggested by Max Planck. It is further of interest to note that the subject-object dualism just touched on has been stressed in very interesting fashion by Niels Bohr.

How shall be conclude our brief survey of the problem of causality in the physical world? I think we may summarize by saying that there is such a thing as the principle of causality in physics and that it has played an important rôle in the building of the physical world. In this world and in this alone does strict causality in the physical sense reign. As soon as we try to make the transition from the physical world to that of our actual sense-perceptions, causality must be associated with the probability concept. However, there is nothing to worry about in this. The task of the physical scientist is to describe events and he is entitled in framing his description to use the most powerful methods which his mind can imagine. If adherence to strict causality entails too great complexity he will fall back on probability, as is evident from the wide-spread and increasing

development of statistical theories. This makes it sound foolish to talk about the breakdown of causality in the more recent theories of the atom. The use of the causal principle is just as possible as it ever was, and if some physicists want to give it up it is only because they prefer to retain the classical space-time concepts as the scaffolding for their theories instead of the more ethereal abstractions of quantum mechanics. The choice is theirs to make; no one can quarrel with them, for in the last analysis the question is one of taste and can never be settled on purely logical grounds. I hope I have succeeded in conveying the impression that the question of causality *versus* acausality, determinism *versus* indeterminism, in the physical world, is after all not so terribly important. We may rest assured that, armed with both powerful methods of description, the physical scientist will go forth to attack with renewed vigor the fortress wherein lie hidden nature's mysteries.

# THE ATTACK ON THE ATOM

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WHAT is the structure of atoms? What is the nature and the arrangement of the parts of which atoms are built? What is the character of the forces that hold these parts together? How much energy do atoms possess and where is this energy located? These are important problems, to the solution of which many physicists are at the present time directing all their energies. The opening skirmishes of this battle for knowledge have already taken place. The rings of outlying fortifications have fallen and we have here but to consolidate the ground gained. The heavy artillery is even now engaged in the final assault upon the nucleus, the central citadel of the atom wherein lie hidden the main treasures we seek. A continuous shower of projectiles has already made some minor breaches in the walls. New guns are hurriedly being brought into action and new weapons ever more powerful are in process of construction. No man can tell how soon the end will come, but be it ten years or a hundred the battle will go on with undiminished zeal until victory is won. Science does not count cost nor ask what price victory. All this activity has not escaped public notice. Every layman is informed through the daily press of what is going on. What is said here must necessarily be in the nature of a survey of the situation.

It may not be amiss to point out at the outset that when we enter the domain of the atom we are on ground where the ordinary laws and concepts of physics, which we use with such confidence in connection with gross matter, have not been tested and may not be directly applicable. It must also be admitted that perhaps we have been too confident as to our understanding of the real significance of the fundamental concepts in terms of which we describe the physical world. Our knowledge of these concepts is in reality limited in character.

Let us consider for a moment the term we call the mass of a body and see in what new light we must look upon this concept when dealing with atoms. We have learned that the electric field about a charged body offers an inertial resistance to accelerated motion and thus has the fundamental attribute which we ascribe to mass. A charged body therefore has more mass than an uncharged one. The smaller the space into which a given charge is concentrated the larger the mass associated with it. By supposing a charged atom sufficiently reduced in size its whole mass may be ascribed to its charge. This supposition has indeed been made in a theory which considers all matter to consist merely of an assemblage of electrical charges. When two oppositely charged bodies are brought near to each other the contrary fields associated with those charges become in part annulled, owing to overlapping, and accordingly a portion of the mass disappears. The sum of the masses of two oppositely charged bodies is therefore greater when they are far apart than it is when they are close together. The effect is really only appreciable at very small distances, but, as we shall see, it plays an important part in atomic structure theory, in what is known as the packing effect.

Furthermore, it has been found that the mass of a charged body increases

when its velocity is augmented. The increase in mass is inappreciable for ordinary velocities, but it becomes great at velocities approaching that of light. Thus the mass of a body is seen to depend on its kinetic energy, and Einstein, by an extension of this idea, made the whole mass of a body depend solely upon its total energy content, be this energy kinetic or potential. Accordingly, when a body loses energy it loses mass. When it gains energy it gains mass. A body radiating energy does so at the expense of its own substance. In this manner, four million tons of the sun's mass are supposed to be transformed every second into radiant heat. Mass and energy are but two different aspects of the same entity. In atomic relations we may speak of the conservation of mass and energy only when the two are taken together and not when considered separately.

Another important generalization made by Einstein must be mentioned. Planck had found it necessary to assume that radiation is not transferred continuously, but that it is given off in definite units called quanta. To account for certain experimental results Einstein considers these quanta of radiant energy localized in small volumes which do not spread during propagation through space. It is thus possible for a quantum of light to be emitted by the atom of one body and be delivered intact to a single atom of another body at a great distance. The electromagnetic wave description of radiant energy transfer can only be considered valid in a statistical sense based on probability considerations.

As far back as 1815, Prout, noting that the atomic weights of many elements are close to being whole numbers, enunciated a hypothesis that the atoms of all the chemical elements are composed of varying numbers of hydrogen atoms linked together. There was serious objection to the hypothesis because of the many exceptions to the whole number rule. The discovery that the atoms of many elements are not all alike and new measurements of their weights have for the most part removed this difficulty. The weights of all individual atoms actually approximate whole numbers when compared to oxygen taken as 16. Nevertheless, the small observed differences from whole numbers are too large to be attributable to errors of experiment. These differences have been accounted for, in a manner already explained, by supposing them due to loss of mass resulting from close packing of the elementary charges that make up the atoms.

But have we no evidence of the structure of atoms that is more positive in character? These objects are naturally far too small for direct observation. How then can we learn anything about them by experiment? We do this by bombarding the atoms with high speed particles or by quanta of radiant energy and look for effects of the collisions both on the bombarding particle and on the atoms bombarded. Observations of electrical discharges through the residual gases in highly exhausted tubes showed the presence there of negatively charged particles having a mass only a little larger than one two-thousandth that of a hydrogen atom. These particles, now called electrons, were torn from atoms by violent actions within the electrical discharge and they are the first chips obtained from atoms. They are found to be building stones, common to the atoms of all the elements.

Since an electron is charged negatively the remainder of every atom must have a resultant positive charge. What can we say regarding the spatial distributions of the two electricities in atoms? Rutherford bombarded metal foils with positively charged particles and from the angles at which these particles were scattered he was led to conclude that the

positive portion of the atom is concentrated into a very small region, only a few millionths of a millionth of a centimeter in diameter. This is roughly about one ten-thousandth of the diameter of the whole atom. Here then started the prevailing theory of the nuclear atom, according to which the atom is a very open structure resembling our solar system. There is a central positively charged nucleus which contains nearly the whole mass of the atom and is its vital portion upon whose integrity the identity of the atom depends. Surrounding the nucleus there is a swarm of electrons ranging in number, in regular sequence for the different chemical elements, from 1 to 92 and arranged at various distances in the so-called energy states or levels. These negative electrons just offset the positive charge on the nucleus so that, at considerable distances, the atom behaves like an electrically neutral body. These outward defenses of the atom have been subjected to intensive study by noting the effects of bombardment with electrons of various speeds and by measuring the frequencies associated with the light quanta that they emit. We already know the energy relations between the different levels and the number of electrons belonging to each level. The energy required to remove one of the outermost electrons from an atom may be stated as equal to that acquired by an electron in falling through a potential difference of but 10 or 20 volts, whereas for the removal of one of the innermost electrons from an atom of high atomic weight an electron must acquire energy by falling through more than 100,000 volts. To account for some of the effects observed it has been necessary to assume that, in some cases at least, the electrons and the nucleus as well are spinning like tops.

As to the exact locations and velocities of the electrons in the different levels, we can but speculate, since these do not permit of direct observation. Bohr gave us an atom model with electrons revolving about the nucleus. This met with success in explaining some of the radiations from hydrogen atoms. Many physicists still like to picture atoms in this way. Chemists, however, prefer to think of a static system of electrons, since the outermost of these electrons serve as bonds for holding atoms together in the formation of molecules.

We come finally to the nucleus, the innermost portion of the atom. Protected as it is by its outer rings of fortifications and by its own formidable wall, how are we to learn anything about what is within? Paradoxical as it may seem we have thus far learned most about the nucleus by doing but little more than use our eyes. Close observation from the outside of some of the families of the heavy elements, like the uraniums and the thoriums and actiniums, brings to light the fact that the inhabitants of these nuclei lead lives full of stress and discord. Here out of the window of one of them we see hurled a large missile with a velocity of more than 10,000 miles a second. Out of another window comes a smaller object having more than ten times this speed. And now here comes, dare we say, an etherial entity so energetic that the likes of it have never been seen before. We gather up these fragments that have been cast into the street. We study them and weigh them. We recognize in the alpha particle a helium nucleus. The beta rays turn out to be electrons and the gamma rays are but light quanta of very high frequency.

Considerations based on wave mechanics lead us to look upon the walls of nuclei as high potential barriers. A charged particle within these walls normally does not have sufficient energy to surmount them, but there is a small probability that now and then such a

particle may pass right through the wall, by means of a window if you like, without loss of energy. Careful measurements made of the speeds of alpha particles, the heavier of the pieces ejected, show that the speeds of the particles coming from any one element are as a rule identical. In some cases, however, groups of particles with different velocities are found, indicating that these came from different potential levels in the nucleus. This view that there are definite potential levels, within the nucleus as well as on the outside of it, is strengthened by the observation that in these cases gamma rays are found with energies corresponding to the differences between the kinetic energies of the alpha particles coming from the same element. The conclusion drawn is that when an alpha particle falls from one potential level to another within the nucleus the potential energy lost appears in the form of a radiation quantum having this particular amount of energy. Conversely, it has been found possible, by bombarding some nuclei with energetic $\gamma$ rays from another substance, to raise some of the alpha particles within them to higher potential levels, as is evidenced by the increased speeds they possess when they get out of an atom under these circumstances.

The recital thus far has had to do with the nuclei of radioactive substances and we have learned that helium nuclei and electrons are contained in these nuclei and that the helium nuclei are at times found in different energy levels differing by definite quanta.

A new stage in the study of the nucleus was reached when Rutherford bombarded the nuclei of ordinary, nonradioactive elements with alpha particles and succeeded in ejecting from some of them high speed hydrogen nuclei or protons, as they are now called. To this third component of atomic nuclei there has recently been added a fourth and lastly a fifth. The fourth component, in order of discovery, was obtained by bombarding elements like beryllium and boron with alpha particles. This new entity is quite unlike the other three in that it carries no resultant charge. It is accordingly called a neutron. The mass obtained for it corresponds very closely to that of a proton. The properties of this new particle are now being studied intensively in many laboratories throughout the world, and it is hoped that its real nature may soon be disclosed. Since the mass of the neutron is approximately that of a proton, two theories proposed for the structure of the neutron both consider it to be a close union of a proton and an electron. According to one theory the proton and electron are held firmly together side by side. According to the other theory the proton is located at the center of the electron, being completely surrounded by the latter. A third more revolutionary theory considers the neutron to be a new elementary particle, in no way related to a proton. Experiments now being carried out on collisions of neutrons with protons appear to favor the last theory. Should this conclusion prove correct we may possibly be faced by the problem of a new kind of force not now recognized. The neutron, because of its uncharged condition, has the power to pass readily through large thicknesses of matter. Its course is only affected by a direct collision with the nucleus of some atom. During such an impact the neutron may be captured by this nucleus, become incorporated in it and either form one atom of a heavier element or after subdivision give birth to two different atoms.

The fifth and last particle to be discovered is the positron. This particle has the same mass as an electron but it carries a positive charge instead of a negative one. The properties of the two

may well be almost identical. Some positrons have been obtained by subjecting atoms to gamma radiation from radium. Others, some with energies as high as 800,000,000 electron volts, either came to us directly from outer space or are ejected from atoms by the action of the so-called cosmic rays.

The experiments on nuclear disruption naturally present difficulties. The nucleus is not only a very small object to shoot at, but we do not even know where it is. We are somewhat in the position of a hunter who fires into the sky on a dark night and hopes to bring down a goose. The only hope of success lies in shooting continuously for a long time with many bullets and trusting that one of them may find its mark.

Until recently the most energetic projectiles at our command have been alpha particles. Their energy is represented by several million electron volts. By their use we have succeeded in knocking various particles out of the nuclei of some of the atoms. Where we have failed, it is possible that the nuclei may possess these same or have other particles so firmly lodged that our projectiles have not been powerful enough to break them away. To overcome this difficulty artificial guns have already been constructed and others are being perfected capable of giving us projectiles even more energetic than alpha particles and many, many times more numerous. No such stupendous physical apparatus has ever been assembled previously. At one university immense spheres 15 feet in diameter, supported by pillars 24 feet high, form a part of the equipment. In other laboratories gigantic magnets of great weight have been built. At other places powerful but less spectacular apparatus is being constructed and pressed into service. No attack so formidable as this has ever been directed against a physical problem.

The purpose of all these great engines is to give electrified particles tremendous velocities and then to hurl them in great number against the nuclei of various elements with the hope of shattering these nuclei more completely than has as yet been found possible. It may well be urged that our method for investigating the machinery of a nucleus is a very crude one; that if we wished to learn how a delicate watch works we would not put it on an anvil and hit it with a hammer. However, we have no alternative. No one has yet improved on the ballistic method of getting the meat out of a hard nut.

With the new equipment already in use a number of nuclei have been shattered, some by use of protons having energies of but a few hundred thousand electron volts. As yet no new types of particles have been obtained, although our knowledge regarding several nuclei has been extended. However, the battle has scarcely begun.

It must be remembered that owing to their scarcity it is no easy matter to detect and recognize fragments of nuclei even after they have been dislodged. Unless a fragment flies off with so high a velocity that we may see the havoc it creates among molecules along its path, we are lost. As larger and larger pieces are dislodged the difficulty of giving them sufficient velocities to enable us to measure their masses becomes more and more formidable.

Composite portions of a nucleus which fly off as one piece are naturally held together by stronger bonds than the bonds which hold these parts to the other constituents of the nucleus. A knowledge of what parts cling together most strongly and of the energies necessary to dislodge them gives us some basis for computing the nature of the forces active within the nucleus. The helium nucleus or alpha particle is a constituent of many nuclei because it is

a highly stable unit. The more elementary particles composing it are held together so closely that its energy content is relatively small, as is indicated by its mass defect, or as this quantity was previously called its packing effect, being unusually high. There is an expectation that particles of half the mass of an alpha particle may be separated out of the nuclei of some of the elements. Such particles would correspond to the nuclei of the heavier isotope of hydrogen, recently discovered. Rutherford has expressed the opinion that we may find a neutral particle of twice the mass of the neutron. An important question to settle is why atoms whose weights are certain multiples of the proton, for example, 3, 5, 8 and so on, are never found in nature. Why are these combinations so unstable?

When we shall have assembled all the pieces we shall be in a better position than now for beginning the work of fitting them together so that we may see the pictures that the different atoms present. Even after the parts of the nuclei are all known and in place, we may still be confronted with unknown aspects of the forces that hold these parts together.

The known problems to be solved are still many, and their solution is almost certain to disclose other and more difficult problems. We do not shirk the task. We are embarked upon a journey that knows no end. We are climbing a mountain that has no top. We do not understand the urge that drives us on. Sufficient for us are the new glimpses of nature's panorama that each forward step reveals.

# THE NEW BURDEN ON BEHAVIOR

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Some years ago when the suggestion was made at a meeting of the British Association for the Advancement of Science that science should take a ten-year holiday, it was received with a smile of indulgence. Since that time, however, there have been recurring expressions of the view that scientific effort should now be turned in other directions than the furthering of our knowledge of our physical environment and our control over it. Professor Millikan, in his chapter on the "Alleged Sins of Science," has attempted an answer to these demands, an answer not wholly convincing. Mr. Julian Huxley, in the course of a lecture at Stanford University, said that one of the next duties of science is to study social life, into the general field of which it has not far advanced.

In the present article, I wish to call attention to certain remarkable social changes which seem to point to the absolute necessity of turning a larger part of the tremendous intellectual power exhibited in scientific thought and research into social and ethical fields, if our western civilization is not continuously to decline. It should be remembered that the trite phrase "downfall of our civilization" does not mean any romantic cataclysm of war or revolution, but the steady decline of our standard of living; at the worst it means dirt, disease and misery. It is not pleasant to recall that in the study of ancient cultures we have to dig down through successive layers of dirt.

Of the social changes to which I have just referred, probably the most significant are these three—our superabundant food supply, our increasing leisure and our shifting standards of behavior. When the "prosperity" for which we are all praying comes, we shall have to face these problems, and we can not do this without scientific knowledge of their interrelations. We shall have to ask how these changes are going to affect the real prosperity of our children, their children and grandchildren. Our interests are almost wholly with economic questions, with the return of good times, with work for all and good wages, with the hum of mill and factory. We have little concern with the to-morrow of our children.

The forgotten man is evidently the man of the to-morrow. Though we may not be interested in any astronomical future of our race, nor in theories of a decadent civilization, we are surely interested in the to-morrow of our children; and sometimes it may occur to us to wonder how their future will be affected by our behavior in the prosperous times which we hope will soon return.

It is just this matter of behavior which is the neglected factor in all our plans for national prosperity; for it may turn out that in human behavior we shall find not only the key to the welfare of succeeding generations, but also the cause of most of our own troubles. Within the period since the world war—one might almost say within the last five years—certain strange things have happened which disturb all our old social views, and may perhaps force us to revise all the old theories of progress.

But let us go back of this for a moment. It has generally been accepted that there are four conditions of human happiness and social progress, and four only. These are: (1) An abundant food supply—abundant and continuous; (2) a favorable climate, including freedom

from destructive floods, storms and earthquakes; (3) a reasonably stable and beneficent government, insuring individual liberty and opportunity; (4) freedom from disturbing wars and foreign invasion. Give us jobs, good wages and economic justice; give us good government and opportunity; give us freedom from war and oppression, and we shall be happy—and well-behaved.

If all this be true and if these be the four conditions of prosperity, then the outlook for the future in America is most alluring, since it appears that all these conditions are to be abundantly fulfilled.

Of the four conditions, that of food supply has always been considered primary. When it fails, primitive people move to other fields or perish from starvation. The English economists predicted disaster for mankind because of the basic law of the rapid increase of population and the slow increase in the food supply. But now it appears that all this is changed. Malthus got his terms mixed. It is the food supply that increases by leaps and bounds, while populations increase slowly or not at all. Science has learned how to increase the fertility of the soil and to decrease the fertility of people. With amazement or even with alarm, we have witnessed in the last few years the accumulating supply of superabundant food. Science has discovered new varieties of wheat suitable for more northern climates. It has invented machines, simplifying the preparation of the soil and the harvesting of the grain. It has discovered new sources of fertilizers for impoverished soils and new methods of irrigation for rich desert lands. It has discovered new means for combating insect pests which threaten agricultural products. Famine, that ancient and persistent enemy of progress, is yielding to the advances of scientific study and experimentation.

But while food was the all-important thing among earlier people, it is now just one of many things which we consider necessary for our happiness and well-being. We want good clothes, good houses, bathrooms, public and private sanitation, public and private electric lights, pure running water, furnace heat, motor cars, radios, medicines, cosmetics, cigarettes, newspapers, books, magazines and a host of other things. Perhaps these will fail in the to-morrow of our children and their children. But no, it appears that there is to be no shortage of any of these things, whether of manufactured articles, raw material or natural products. Already we have factories and skilled labor for supplying not only our own people but many others with manufactured goods of every kind. And an army of technicians awaits our call for still other articles of production and for means of supplying them.

The second condition of human happiness, namely, favorable climate, need cause us no concern. Nineteenth century fears of a gradually freezing planet with visions of the last forlorn inhabitant shivering over a pile of dying embers have vanished with our new astronomical knowledge, and we are now assured that Mother Earth will offer a genial climate, well fitted for human happiness, for at least a million years. "Fair and mild" is the weather forecast for the next few hundred thousand years. Earthquakes will occur more rarely, and storms will gradually become less destructive.

But what about our third condition of welfare, that of a reasonably stable and beneficent government, guaranteeing protection, freedom and opportunity to all the people? Here again the future is bright with promise. All the tendencies of our modern era are steadily in the direction of greater political stability and the increased beneficence of governments. National boundaries become more and more sacred, and international relations are determined more and more by reason and justice, and less by mili-

tary force and oppression. Even when a far distant oriental nation ventures with its armies across the boundary line of another people, the protests of all civilized nations as well as those of many of its own people are heard around the world. Relations also with colonial possessions are more and more governed by motives of benevolent service, and less by those of commercial and industrial exploitation.

Neither can we doubt the beneficence of the political state of the future. Revolutions will occur, as they are occurring now, and in times of economic depression they may multiply; but they tend more and more to be bloodless, and the daily routine of the people goes on much as before. A labor government comes into power in England, and no great change takes place in the relations of the people to the government. In Fascist Italy, in republican France, in imperial Britain, in democratic America, there continue to be public schools, public libraries, public care for the helpless, the sick, the insane and the feeble-minded, state inspection of foods, pure food and drug laws, sanitary regulations, the education and protection of children, increasing rights and privileges of women, safeguarding of the rights and wages of workers, efficient police protection, convenient postal and telegraph systems, improved public highways and airways, various forms of social insurance, state regulation of systems of transportation, and so on through the long list. These are merely illustrations of a public beneficence with which we have become so familiar that we take it all for granted. No government would long endure that does not provide such things. Governments are becoming more and more efficient, and government is becoming more and more an exact science.

In the America of to-morrow, as in other states of the western world, we can not doubt that these and many other forms of public beneficence will be present. Experiments in the form of government there will no doubt be. Capitalism, collectivism, socialism, conceivably even Fascism or communism may be tried; but the state will go on, and there will continue to be colleges, universities, free public parks, art galleries and museums. We shall still be able to send our letters across the continent or to foreign countries for a few pennies. There will still be telephonic communication around the world, and we can still ride comfortably and safely by water, rail or air. For the government of the future, then, we may confidently predict both stability and beneficence, and an increasing degree of each.

Now what of the fourth condition of human happiness and social welfare, namely, freedom from war and from foreign oppression? Here also we may look to the future with hope and confidence, not only in America, where confidence is the greatest, but throughout the world. An increasing number of men and women of every land are becoming conscious of the hopeless futility of war. They are beginning to understand its frightful cost, financial, economic, political, social, biological and moral, and its monstrous waste. It is this wide-spread growing consciousness of the iniquity and uselessness of war which from generation to generation will lessen its frequency. Furthermore, a wholly new and powerful motive toward the maintenance of peace has arisen. The interests of the western world have become primarily commercial, financial, industrial and economic, and secondarily political; and all these new interests have taken on intricate international relations, into which war enters as a fatal disturbing factor. Finally, war itself has been made somewhat ridiculous, owing to the leading rôle which the moving picture industry and the feverish news service industry now take in the actual drama of war. When battles begin to be filmed, they will soon cease to

be fought. Wars no doubt there will still be, but they will steadily become less frequent and less important. The destiny of nations in the future will be determined not by war but by the integrity, sturdiness and discipline of the people.

It appears, then, that the four traditional conditions of prosperity will be abundantly fulfilled in the to-morrow of our children. There will be a more than adequate food supply, even for increasing populations. There will be favoring climate, stable and generous governments and a growing freedom from devastating wars.

*And yet few writers in any field of physical or social science, literature, art, or philosophy venture to predict for the future any degree of social welfare or human happiness commensurate with our wealth and our opportunities, while predictions of a complete collapse of our western civilization are many and portending.*

How shall we explain this strange situation? The explanation is not far to seek. It is because in our modern complex society there is another condition of prosperity and happiness than plentiful food, manufactured goods, friendly climate, good government and peace among nations, and this other condition is human behavior; and, owing to the complex character of our present civilization, and the new and crowded relations under which we live, this new condition of prosperity has become supreme and overshadowing. The old cry of the people, "Give us jobs, give us peace, and give us the right kind of government, and we shall be prosperous and happy," must in the future be supplemented by a conditional clause—provided we behave like human beings.

The old idea that crime will disappear with the advent of the full dinner pail and that with the coming of economic prosperity, the people will devote themselves with industry and sobriety to honest toil, spending their leisure hours in creative art and in innocent amusements, has been long since discredited. In those overflowing years preceding the great depression, we had jobs, we had money, we had peace with other nations, and we had a stable and beneficent government, but our jails and prisons were crowded and the era of gangsters and organized crime began in our cities.

That the sorrows and sufferings which in earlier communities followed from famine and flood, war and invasion, and the oppression of ruling classes and tyrannical governments, are due in our modern society to human misbehavior and to human folly and incompetence is apparent as soon as we begin to reflect upon it. Our thought naturally turns first to the depression, and the catalogue of its causes is gradually taking form. But whether these causes are to be found in our imperfect economic organization, our fanatical neglect of any rational adjustment between production, distribution and consumption, our wasteful competition, our unorganized individualism, our reckless and greedy speculation, our thoughtless enlargement of industrial and commercial enterprises, our popular extravagance and waste, our foolish misuse of instalment buying and selling, or finally in our artificial restriction upon international trade through unwise tariffs and the overturning of normal trade relations by the post-war system of reparations and war debts, it is evident that it all comes back to somebody's mismanagement, incompetence, folly or misbehavior.

Or, if we choose, however wrongly, to trace the whole trouble back to the war, the war itself was a gigantic misadventure, having its roots in foolish international rivalry and jealousy. We are coming now to regard the world war as a series of fatal blunders, of which the Treaty of Versailles was the crowning example, unless we except the failure of the United States to assume at that time

the generous leadership, political, economic and moral, which was within its grasp.

I have taken the economic depression as an illustration of the fact that in this modern era our many ills are due to our many errors. But any other illustration would have done as well. If, for instance, we try to discover the ultimate sources of the crime wave with its organized banditry, its bootlegging, racketeering and kidnapping, we come back always to some form of human greed, corruption or incompetence, or to some form of physical or mental defect. The story is the same, whether we trace our crime to delay in the administration of our criminal laws or to our dilatory courts, our weak juries, our corrupt officials, or our venal politicians.

In many cases, we find the source of crime in the behavior of fathers and mothers, leading to the birth of children with abnormal brain patterns or glandular deficiency. Possibly slenderizing fashions, high-heeled shoes, immoderate or indecent dancing, cigarettes and cocktails on the part of mothers may have something to do with bad behavior on the part of sons and daughters.

Possibly, indeed, we should go still further back in our search for the cause of crime and find some of it in human interference with Nature's selective method of breeding a hearty and healthy race. We tremble for the nation's future when we are told, for instance, that every second bed in our thousands of hospitals is occupied by a person having some form of nervous or mental defect.

Just now it is the fashion to place the blame for our crime wave upon our prohibitory laws. But in any case it would go back to the lawmakers or the lawbreakers. Somebody went wrong, whether we put the blame on unwise legislation or on wilful disobedience to law or on mass emotion and hysteria of a fickle people, soon tiring of their self-imposed temperance. If the law was a bad one, we did wrong in making it; if it was a good one, we did wrong in breaking it. The spectacle, at any rate, of a great nation quarreling over the percentage of alcohol which it can have in its drink, at a time when really serious and fateful economic and political problems are before it, is certainly not edifying. It is ludicrous and humiliating, and makes us appear like a nation of children.

The recent rapid increase of divorce, the threatened disintegration of the home, the emphasis of sex in present-day fiction and the moving pictures and the advent of "easy standards" among both young and old are all deeply significant social changes, placing a new burden upon behavior as it relates to the future health and happiness of our children and to the endurance of a strong and virile nation.

The front-page headlines of a metropolitan newspaper announce that a celebrated tennis queen lauds woman who breaks conventions, and an advertisement in one of our standard monthly magazines praises a new book as "an exquisite story of love transcending all conventions" and breaking through the barriers of false morality. This is "the new freedom for women."

The increasing cigarette habit may or may not be for the nation's hurt, but it indicates a serious social change; and when the publisher of a widely circulating magazine must decide whether he will or will not for a glittering sum accept a highly illumined and seductive advertisement of smokes for women, his decision is of great social import.

These instances I mention not to pass judgment upon conduct or customs, but as an illustration of the burden of social responsibility which rests upon editors, publishers, picture producers and writers of fiction. The social responsibility of the teachers in our schools has always been recognized; but the change has

been so sudden that we fail to comprehend to what extent the education of the young is now in the hands, not of our schools, but of the daily and monthly press, the news stand, the circulating library, the moving pictures and the radio.

In former times there was no such burden upon individual behavior and no such responsibility resting upon those holding positions of influence, since conduct was regulated by custom. Those social groups whose customs did not have a favorable balance of survival value perished or were reduced to slavery in the fierce struggle with other hostile groups or with the forces of nature. In modern times behavior has become reflective rather than customary, and great issues depend upon the reflection and decision of the individual. If behavior should become neither reflective nor "customary," but impulsive, organized society would be near its end.

Since then the happiness and prosperity of ourselves and our children depend not upon the mood of Nature, or our physical environment, but upon human behavior and our social environment, it becomes of supreme interest to inquire what equipment the man of the present has for bearing this new burden.

A candid answer to this question reveals a strange situation. It appears that, although every other science has been developed to a high degree, the science dealing with the relation between human behavior and human happiness is in its infancy. We have no exact scientific knowledge of good behavior comparable with our knowledge of the physical world possessed by our astronomers, physicists, physiologists and chemists. And in this connection let it be clearly understood that by good behavior we do not mean that which conforms to any ancient code of conduct or to any moral custom or tradition, but solely that kind of behavior which is necessary for human happiness and social health, both for the present and coming generations.

In the field of behavior our knowledge is fragmentary and chaotic, and our attitude toward such problems differs wholly from our fine confidence when we face the problems of science, even those of the most abstract and difficult kind, such as the theory of relativity or the nature of space; and we have no company of great minds and distinguished scientific men working upon the problem of behavior, and no great public interest to inspire the search and reward the solution. There is probably more public interest in dispelling our ignorance of the interior of the Antarctic continent than in solving the problems of human behavior as it relates to the health and happiness of our children; and our equipment for answering the geographic question is better than for solving the social one. And yet unless we can solve this social problem, our whole wonderful and really great civilization is in peril.

Nothing could be more fraught with danger than the confusion and bewilderment which exist in the minds of our people, both young and old, about such questions as the position of divorce in a healthy social group, the relation of the sexes both before and after marriage, the effects upon racial health of the constantly increasing use of alcohol and tobacco, the limitation of desires *versus* increase of production, the social advantage of saving *versus* spending, the relative value of self-expression *versus* self-control, the social responsibility of our writers of fiction and of publishers, editors and producers of pictures, the conservation of racial health and the practice of birth control. There is not only no code of behavior in respect to these various issues but there is no exact knowledge regarding them, and no fact-finding commission investigating them, and no plank concerning them in the platform of either of our great political parties.

Furthermore, as our civilization becomes complex and our communities crowded, a new burden is placed upon all the old virtues which experience has found to be necessary to communal living, such as respect for life and property, the sanctity of marriage and the home, justice, honesty, veracity, fair play, temperance, cleanliness and chastity. Civil law can attempt only a partial regulation of these and only in cases of serious violation. For the rest we depend upon ancient codes of conduct, tables of commandments, custom, public opinion and religious authority; and something very near to chaos exists today, not only in respect to the validity of these codes, but also in respect to the sanctions for them; and we are without scientific guidance in this matter. These ancient codes have come down to us by social inheritance and are unsifted and unverified. We demand to know whence they come and what their credentials are.

Divine authority has often been claimed for the traditional codes of behavior, possibly, we mistrust, by zealous though not quite truthful priests and prophets of religion. But we demand to know whether God has indeed ordained them; and, anyway, we wonder what kind of laws would be made by an all-wise legislator, legislating for a machine age like ours, with its congested cities, its complexities of industry, finance and international relations, its conflicts between labor and capital, its increasing longevity and decreasing fertility, its revolutionized position of women, its unhappy gap between the age of puberty and the age of marriage, its craving for sedatives such as alcohol and tobacco, its abundance of leisure, its new scale of values in an age of sports and recreations, and its new and bewildering Freudian psychology.

It is partly our prevailing skepticism and partly our feeling that the traditional laws of behavior are not adapted to our new age that has cast a shadow of doubt upon all the ancient *mores*. But the fatal result has been that in discarding the rules that were bad, we have rejected those that were good. There is danger, indeed, that we may reject those that are vital to all social living, those that have through all the centuries grown out of the hard experience of social groups.

And we have no Five Year Plan for establishing a national code of behavior which shall separate the true from the false in the old conventions; nor have we any such plan for adapting by scientific examination the ancient codes to modern conditions. We have fact-finding commissions to report on the economic and financial problems of the day, but no such commissions or advisory councils or committee of experts to determine which of the old rules of behavior were just taboos or silly conventions and which are vital conditions of social survival.

The solution of this whole fateful problem seems to lie in giving a new direction to both theoretical and applied science. Whether the spirit of the age will change in time to effect this new direction is a question which no one can now answer. Science has surrounded us with comforts and conveniences, increased our life span and changed our daily habits; it is now time to study our behavior in this new environment. We have plenty of gadgets of all kinds for dealing with the material world; but our equipment for successful communal living is out of date. We need a genius like Einstein to tell us not any more about space and gravity, but how to behave in this new and perplexing world—and why.

Our most pressing need to-day is a new set of ideal behavior patterns. Those that we have were adapted to sparsely inhabited agrarian communities. They are now as much out of date as a tallow candle for lighting our homes, or

a horse and buggy to carry us to the city. Science has given us electric lights and motor cars; now let it give us a new set of behavior patterns. If it is replied that the task we propose is beyond the power of all organized effort and beyond the wisdom of all our wisest men, it must be remembered that this is what has been said concerning most of the miraculous achievements of modern science.

In fact, we are turning more and more to the experts in all fields of endeavor, for instance, in the field of government. Even if our members of Congress should be chosen because of their intellectual power, they could not solve the complex problems of government to-day. We depend more and more on commissions of experts in the several fields. Ignorant audiences applaud satirical jibes at government by commissions and approve of proposals to abolish them and balance the budget; but we need more of such commissions—not fewer. We need men who know. We need them for economic planning; we need them still more for social planning. Plato explained all this to us more than two thousand years ago, but we have learned his lesson poorly.

Of course, there is that other age-old problem concerning the forces or sanctions which society can bring to bear upon individuals to ensure obedience to ideal codes of behavior, but it is perfectly obvious that the first step in this direction is the authoritative establishment of such codes, and the authority of science is the one thing which the modern man still respects. The forces of social control which have been effective during the history of mankind are custom, public opinion, religious authority and the authority of the state or its representative. But the commanding force of both custom and religion has become greatly lessened. We demand to know their credentials. And as for the authority of the state, our late experience with prohibition has revealed to us the difficulty in enforcing laws for which the people do not see the need. The people themselves demand to know the reason for the law.

In former times it was enough to know that God had said Thou shalt, or Thou shalt not. Again it was enough to know that the chief or king had issued a command. And again through all the ages it was enough to know that it was the custom of our fathers or of our neighbors. But times have changed. We want to be shown. And science is the only authority left to show us.

But if we are shown, will we obey? or have we become essentially a lawless people? If any one thinks that we are not a law-abiding people when we can see the purpose of a law, let him study our traffic regulations. Let him take his stand at some busy crossing of one of our great motor highways. Probably no officer is in sight, but hour after hour, day and night, the drivers, with machine-like regularity, bring their speeding cars to a stop before the red light and again move on with decorous precision at the flashing of the green; and they prate not of personal liberty or inquisitorial laws or the right to regulate their own cars according to their own views. They stop when the signals say "Stop." And the reason for this docile obedience is clear. We love to drive our cars, and even the dumbest of us can see that the traffic laws are necessary to that end. The penalties are swift and certain, and public opinion supports the regulations.

It is not alone in the case of traffic rules that we are a law-abiding, humble and decorous people. Similar discipline is seen in the conduct of our sports, of our large commercial houses, of our transportation service, and in many other fields. But in all these faithfully observed rules and regulations there is one clear and definite end, namely, that

we may carry on in the pursuits in which we are vitally concerned—in industry and commerce, in sports and recreation.

In the case of laws or social customs which relate not to our immediate interests but to the conservation of social or racial values, such as the health and happiness of our children and the integrity and stability of our nation, it is difficult to mobilize public opinion in enforcing laws or conserving customs. To take a single instance, it may well be and probably is true that the social and racial damage done by the use of alcohol is almost infinitely greater than any injury done to life or property resulting from the infraction of our traffic laws. But we do not know this to be true, although laboratory experiments and the experience of social workers seem to confirm it. The question must be passed upon by those who know, and by those in whose word the people have confidence. The solution of the wet and dry problem seems then to lie in the field of scientific inquiry and authority, and when science has spoken, its decisions must be made known through every educational channel, the school, the daily press, the radio, the movies and the news stand. Whether in a democracy like ours customs can be conserved and laws passed and enforced which relate to a future no more distant even than the maturity of our children is a question which only time can answer. My purpose in this paper has been not to discuss this subject but only to call attention to the new and terrific burden which modern society has put upon behavior, and to express the belief that this burden can be borne only when the enormous power of scientific thought has been turned in this direction.

# THE USES AND LIMITATIONS OF THE STATISTICAL METHOD IN THE SOCIAL SCIENCES

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CONTRARY statements as to the scientific value of statistical methods and quantitative analysis abound in the present-day literature of the social sciences. Thus Professor Howard Becker in his "Systematic Sociology" says that "sociological problems are not quantitative problems at all." On the other hand, in all the theoretical social sciences considerable schools have arisen of recent years which claim that the only way in which social studies can be made scientific is by the use of the statistical method. These social scientists apparently subscribe to Karl Pearson's aphorism that "science is measurement."

Now I am not prepared to endorse either the dictum of Professor Becker or the aphorism of Pearson. It seems to me that some of the basic problems of human society are physical and hence susceptible of quantitative statement. In such cases quantitative methods enable us to state the problem in more definite terms, and indicate to us logical possibilities. Such, for example, are in the main the problems of population. But it would also seem to me that science can be measurement only when it deals with those aspects of reality which are subject to quantitative statement, and that there is perhaps no greater source of confusion in the social sciences at the present time than blind adherence to such an aphorism as Pearson's. It would seem to me that as we ascend in the scale of life the view that science is quantitative measurement of objective conditions becomes less and less applicable, not only because measurement becomes more difficult, but because the subjective element plays a larger part. Even if the subjective element is capable of certain measurements and even if it is true that whatever exists exists in some quantity or number, nevertheless, it is obvious that where subjective elements play a large part, measurement becomes of less importance for accurate knowledge because it is confined to the superficial aspects of the total situation and fails to expose the nature of the process which is being investigated. This is especially true in the social sciences and in them measurement seems to me to play a rôle secondary to other scientific methods.

If this is the actual condition in the social sciences, it explains the contradictory statements regarding the value of measurements which we find in present-day literature. It is obvious that Pearson was thinking of the physical sciences when he said that science is measurement, and it is probable that those social scientists who hold to substantially the same view have been unduly influenced by the development of methods of measurement in the physical sciences. On the other hand, it is obvious that Professor Becker, in asserting that sociological problems are not quantitative problems at all, is thinking of the systematic analysis and classification of social situations and processes which must be made before statistical measurements can be fruitfully undertaken.

But the radical reason for opening up afresh this much-discussed question of the place and validity of the statistical method in the social sciences is the rise and triumph of the cultural conception

of the human society. This new conception, which was alien to practically all social thinking a generation back, puts human social behavior in a class by itself among objects of scientific investigation; for there is no analogue of human culture in the rest of nature. As yet, however, those working in the field of social sciences have not come to see clearly that the value of the statistical method in those sciences is necessarily conditioned by the nature of human society. If the study of culture has revolutionized our conceptions of that nature, then it must also revolutionize our conceptions of the method appropriate to the social sciences.

I mean, of course, by "science" theoretical science. The knowledge which theoretical science gives us must be of a universal character. A scientific generalization is one which will hold anywhere under given conditions. Scientific generalizations in this strict sense rise above the temporal and local. They hold universally. So great is the stability of physical nature that most measurements of physical processes under given conditions do hold universally or nearly so. The question is whether such measurements are possible in human society, and if so how far can they go? Is there the same fixity or stability in social processes, so that measurements once made and correlations once established will, like those of physical nature, hold universally?

Now, the cultural conception of human society is revolutionary for the social sciences just because it emphasizes that all our social institutions and social arrangements are historical, cultural products. The social life and the social processes of the Eskimo, for example, are products of their history—of a process of invention, learning and adaptation which began in remote times and which has been continually changing down to the present. But this is equally so of the social life and the social processes of the American people. According to the cultural conception of human society, human societies are what they are, not so much through the working of natural forces as through processes of invention and learning. The whole institutional and social life of a people has been produced by learned adjustments, and, so far as we can see, will be subject to indefinite modification by invention and learning in the future. Therefore, the social phenomena which we undertake to measure by the statistical method are historical products, as much so, for example, as private property or democratic government. Such social phenomena are subject to change by further invention and learning and rarely show the stability and fixity which we find in physical nature. In other words, social reality is dynamic, while the phenomena which the physical scientist is called upon to deal with are relatively static.

Now, something of the difficulty of the measurement of social phenomena has been perceived by our greatest statisticians. We find Professor G. Udney Yule, for example, saying, "Statistical methods should be regarded as ancillary, not essential" in the social sciences.[1] To take another example, Mr. Malcolm C. Rorty, who was president of the American Statistical Association in 1930, in an address before that body,[2] demanded that statisticians be logicians and scientists in the broader sense, and only secondarily users of statistical techniques; for, he said, all statistical conclusions needed to be reached primarily through logical and experimental processes, supplemented by simple numerical and graphical analysis. He added that the verification of conclusions by means of controlled statistical methods is very rarely possible in the social sciences, and

[1] *British Journal of Psychology*, Vol. 12, p. 105. Quoted by Young, "Social Psychology," p. vii.

[2] See *Journal of the American Statistical Association*, Vol. xxvi, pp. 1–10, March, 1931.

warned against the assumption that a coefficient of correlation establishes any presumption whatever as to cause and effect relations between social variables. Thus apparently Mr. Rorty would restore logic to the supreme place in scientific methodology.

But other users of the statistical methods in the social sciences are not so careful as these leaders. Apparently many of them think that the statistical method is capable of giving measurements and correlations of universal social validity. Thus in the very issue of the *Journal of the American Statistical Association* which contains Mr. Rorty's address there is an article on "The Influence of Population Density on Crime," by a Canadian statistician, in which the conclusion seems to be reached that there is a definite correlation between population density and crime. If so, it would be hard to explain why the crime rate in Great Britain is only one tenth that of the United States, while the population density is many times greater. As soon as we understand, however, the differences in the historical culture of the two peoples, the reasons for the differences in crime rate become apparent without the use of statistical measurements. The factors which enter into the crime rate are quite evidently historical and cultural conditions and are very variable.

There is a considerable number of the less critical advocates of the statistical method who seem to hold that in the more fundamental processes of human society statistics give measurements and correlations of universal validity. For example, they seem to think that when it comes to certain biological functions these functions are the same under all conditions of culture. Thus we have the statisticians of population laying down laws which hold universally for the growth of population. They point to the logistic curve which population statistics seem to follow under certain circumstances. Similarly, we have those who argue that the more fundamental aspects of economic life are also the same under all conditions of culture, and we have economic texts which are filled with statistics, graphs and curves which are held to be true of human society, if not everywhere, at least in the long run.

Now, I am not prepared to say that there are not physical and biological conditions which hold universally for every human society of which we have knowledge, and which would, therefore, give universal correlations between these physical facts and social facts. If such correlations exist, however, they probably concern processes which are not distinctively human, but concern animal groups quite as much as human groups. But the distinctive mark of human society, and ordinarily of all that we call human, is culture. If correlations exist between physical facts and social processes, they interest us as social scientists only in the same way that we are interested in physical and biological science as a foundation for social science. They do not explain the distinctively human in social processes and conditions.

Moreover, all such correlations, the greatest statisticians are beginning to tell us, are of doubtful universal validity. Thus at one time we thought that a definite correlation could be discovered between the density of population and the death rate; but modern sanitary inventions are making any such correlation doubtful. Again, the incidence of disease and death varies so much in human societies under different cultural conditions that few, if any, correlations which will hold universally can be discovered. Again, we used to think that there were very definite correlations between the birth rate and economic conditions. But the discovery and popularization of methods of birth control have made such correlations doubtful, because the use of these methods is motivated by other cultural conditions than the economic. It might almost be said

that it is doubtful if any correlations of universal validity exist in the field of vital statistics. Correlations which are found seem to have, at most, only a relative validity, that is, relative to a given culture. But vital statistics represent the most physical aspect of the human social process; and if universal correlations can not be found in this field, we may doubt if they can be found by means of statistical measurements in other social science fields.

Let us use one more illustration to make clear the relativity of all statistical measurements, if they concern cultural appliances and conditions. The illustration is the mortality statistics of automobile accidents issued by the Federal Bureau of the Census and other statistical agencies. We notice at once that these statistics vary greatly from place to place, and if we examine them in time, from year to year. While certain correlations are discoverable between automobile accidents and the number of motor cars, the density of the population and other conditions, they do not seem to hold universally. If, for example, we get a correlation between the number of accidents and speed in driving, we find that such a correlation holds only for a given stage of the development of the automobile. A new invention may make high-speed driving much safer and the correlation disappears. Thus, it is safe to conclude that statistical measurements of human social processes are so affected by the development of culture, that they hold only for a given time and place, are relative to a particular phase of culture, and are only indirectly of value for the construction of theoretical social science.

I am not, of course, raising any question as to the practical value of statistical measurements for the guidance of social action. Just because such measurements are relative to the place and the time in which they are made, they are of the greatest practical value. The statistical method can, in a word, give us two sorts of knowledge which we greatly need for the guidance of social action. Statistical methods, when rightly used, can show us, first, what are the social facts, and, secondly, when extended in time, what are the trends in our society and civilization. Statistics thus lay a factual foundation for social theorizing and indirectly they may contribute greatly in this way to social theories which are of universal validity. As Professor Yule says they should be regarded as ancillary, not essential, in the social sciences. They become essential only when we attempt to apply our social science to the interpretation of present human society. Then we need to know to the fullest extent possible all the factors which are influencing social occurrences among us, such as births, deaths, accidents, market prices and the like. It is only statistics which can tell us accurately about movements and tendencies in present-day society. Moreover, I am inclined to think that many of the newer methods developed by statistical science, such as "sampling," are more valuable for revealing current tendencies than their critics suppose. The "straw votes" undertaken by such enterprising periodicals as *The Literary Digest* have turned out to be surprisingly accurate. It would seem that we can rely upon the method of "sampling" to discover trends in our civilization much more than what we had supposed.

But even so, a limitation of the practical values of statistics comes immediately into view. If statistics can show us facts and trends in our present society, we must remember that these facts and trends may sometimes be changed overnight by new inventions, new discoveries or a sudden change in the emotional reaction of a population. A fact is local and temporal and a trend is temporal. Both are limited by conditions of time and place. A change in culture may bring a change in the correlations which statistics reveal between local conditions

or between temporal conditions. The demonstration of a fact or the demonstration of a trend in no way shows what is inevitable or unchangeable in human society. We doubtless need more and better statistics for the guidance of social action, but we shall continue to need careful, logical interpretation of these statistics before we make them a basis for practical policies.

The utility of the statistical method in the social sciences, therefore, turns out to be very much like the utility of the case-study method. Both are indispensable for the understanding of our present civilization and social life, and these methods it is needless to say are not opposed, but supplement each other. The followers of the case-study method should make a larger use of statistics, and the students of statistics should get down to the study of concrete cases. Both methods fit in also with the historical method and supplement it. The time has surely come for every student of the social sciences to acknowledge that only a composite method, which shall include all methods of securing reliable knowledge, is an adequate instrument of research in the field of the social sciences.

So far from this being generally acknowledged, however, we find a considerable school who tell us that only quantitative methods in the social sciences are worthy of being called scientific and that the social sciences of the future will become, if not speedily, then ultimately, wholly quantitative. Thus we find one writer of this school asserting that "the new content (of the social sciences) will consist of the statistically summarized results of a large number of behavior records in all fields of social behavior." This, is perhaps, an extreme example of the attitude of the behaviorist in the social sciences, but it shows clearly the effect upon the social sciences of a one-sided advocacy of the statistical method, despite the cautionings of the great leaders in statistics. According to this view the scientific character of any text-book in any of the social sciences could be determined by simply measuring the pages devoted to "statistically summarized results," assuming, of course, that these results have been reached with meticulous care by statistical experts. The writer of this prophecy, however, forgets that all the great texts in the social sciences, from Adam Smith to the latest text in social psychology, political science or economics, have consisted much more largely of careful logical reasoning than of "statistically summarized results." And we have every reason to believe that this will continue to be so, if the positions taken in this paper are sound, in any future development of the social sciences which we can foresee.

For, to summarize, it is very rarely possible to discover in social statistics correlations which are universal, such as science in the strict sense demands. The social phenomena which we can measure by the statistical method are historical cultural products which vary independently from day to day and place to place. They can, therefore, be rightly interpreted only when viewed in the light of cultural and historical development. Statistics are indispensable to show existing social tendencies; but if they are taken in the social sciences as revealing rigid and universal correlations, or "laws," they lead to grave sociological fallacies. While we need better statistical measurements of social movements, we need more philosophical and historical insight in interpreting them.

# PATHOLOGICAL ARSON

By Professor JOHN H. MAGEE

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THE losses arising out of the destruction of property each year by incendiaries reach figures of staggering proportions. Millions of dollars in values, that might otherwise be preserved for the benefit of society, are destroyed through this agency by fire.

Authorities concerned with the investigation of losses where arson is suspected are of the opinion that it is the tendency to underestimate the extent of incendiary fire losses. It is pointed out that when a fire is deliberately set, the individual responsible sees to it that he does a good job, while accidental fires may be, and often are, checked before any serious damage occurs. While 25 per cent. of all fires are not due to incendiarism, reliable estimates have placed the loss due to incendiarism and arson at 25 per cent. of the entire fire loss.

It is ordinarily supposed that the prime cause of the deliberate destruction of property arises out of the desire to defraud insurance carriers. It is indeed true that incendiarism made its appearance as an instrument for perpetrating fraud when the insurance idea was in the very process of development. In fact, the depth of degradation to which men have stooped to defraud insurance companies is appalling and little realized by others than those near the business. There is, however, a source of incendiarism that involves no moral turpitude, may strike anywhere at any time and spread death and disaster in its wake.

The records are lurid with disastrous fires, deliberately set by individuals affected with a form of mental derangement. The term "pyromaniac" as applied to those acting under an irresistible impulse to set fires is familiar to every one. The popular use of the word, however, has led to its employment oftentimes where there is no mental aberration, and for that reason the term "pathological arson" has been offered as a substitute for abnormally motivated fire setting. Under this broader heading we may include the morbid propensities which give rise to pyromania, cases of mental conflict, feeblemindedness and epilepsy. Healy defines pathological arson as "fire-setting under an abnormally conditioned impulse by a person not determinably insane."

If the form of mental abnormality which gives rise to the threat of disaster were easily recognized, then there would be no problem. It is out of the subtlety of the difficulty that the danger arises. Pyromania, for example, is one of those difficulties recognized by the presence of persistent ideas. Such troubles present themselves in many different forms. An idea rises into consciousness, and the patient is powerless to overcome it. When the idea forces itself into his mind it crowds out all others and becomes a source of great discomfort and inconvenience. These forms of mental disturbance may occur in otherwise mentally normal persons. Such ideas may be nothing more than a number or sentence or the like, forcing its way into the mind of the patient against his will, but involving no overt action. Pathological tendencies are not at all uncommon and frequently present themselves in a manner giving rise to no serious consequences.

Closely allied to the derangement arising out of the presence of insistent ideas is that involving morbid impulses. It is

this in which we are here interested. In this difficulty the uncontrollable impulse to do something takes possession of the patient's mind with such force and power that restraint seems impossible. Impulses of this type, as soon as they appear in the consciousness, may pass immediately into action. Impulses associated with intense morbid emotional states are termed morbid propensities. Here we find pyromania.

A patient suffering from a morbid propensity has an impulse to do a certain act. From the point of view of fire-setting we get a better understanding of the situation when we realize that such a patient, when acting upon a morbid impulse of this type, is not only fully conscious of what he is doing, but in addition oftentimes derives great pleasure from its accomplishment. The number of such morbid propensities is great, differing widely in their nature and character, some harmless, others a menace to life and property.

The mental attitude of the pyromaniac is illustrated by a plea presented to a judge by an individual on trial for arson. Admitting his guilt in setting the fire of which he was accused, he pleaded that when the impulse to burn overcame him, even though he knew it was wrong, he was powerless to resist. The records show that the judge sentenced the accused to twenty years at Sing Sing. It must have appeared later, however, that the case was one of mental abnormality, for the accused was transferred to the Matteawan Hospital for Insane Criminals.

The damage that a pyromaniac free in a community can accomplish is almost incalculable. There is reported an instance of a member of the fire department in a central Western city who confessed responsibility for setting twenty fires. A nurse in a hospital set fire to the building, causing sixty-five deaths. A youth in an Eastern state, charged with arson, confessed to burning thirty buildings, with losses aggregating approximately $170,000. In another town there were over fifty suspicious fires covering a period of five years. Some of the buildings were inhabited dwellings, from which the occupants had to be rescued, to save them from the fire. Over twenty of these fires were traced to the same mentally unbalanced individuals. A list of examples could be carried to interminable length. A final case will serve as typical and admirably suited to illustrate both the amount of damage a pyromaniac may do and the difficulty of his apprehension.

One fall morning two fires were discovered in a hotel located in an Eastern city. The first occurred in a vacant room, the other in a linen closet. Because of the suspicious nature of the fires state police were called in to investigate, and it was soon learned that similar fires had occurred in five other hotels in cities located near-by. A check of the registers disclosed that at the time the fires occurred there was but one guest present at every fire. Naturally, suspicion was directed toward him, and he was subsequently arrested. During the investigation this individual confessed to setting not only the five fires in question, but a great many others in other cities and in distant states. A check of fifty reported hotel fires showed that this man was registered as a guest in over half of them, and it is possible that he may have been the cause of fires that gained such headway as to make it impossible to determine the origin, as well as destroying the records.

Before leaving the case, a word about the young man is of interest. There were no peculiarities reported by the investigators that would indicate any mental difficulty other than the propensity to set fires. He was to all appearances normal, able to go about his business and

hold his job. A press notice at the time of his arrest stated of him: "He is described as a man of superior education and is employed by a reputable Chicago firm. It is apparent, the police said, that he is suffering from pyromania, and he could assign no reason for his acts beyond the satisfaction of his desire to behold destruction by flames."

Because the mental illness of the pyromaniac manifests itself in no other way than through this propensity to set fires, such individuals are extremely difficult to apprehend. They are often possessed of unusual craft and cunning, though such individuals are becoming better understood through the scientific study of psychiatrists and psychologists.

Certain characteristics of the pyromaniac are worthy of note. He is said to be almost certain not to leave the scene of the fire he has started, or if he does he will just as certainly return, because only through watching the fire he has set does he derive the satisfaction that he craves. Possessing this knowlledge, investigators have come to watch for the pyromaniac among the onlookers at the fire. Then there are individuals suffering from this difficulty who show a tendency to start fires in a certain way or in certain circumstances. Such an instance was cited in the case of the young salesman who started the fires in hotel rooms. In an epidemic of tenement fires a number of them were traced to a single individual, who always started them in baby carriages left in hallways. Others are attracted to special type buildings, such as barns, schools or churches.

An unfortunate angle of this problem is the frequent failure of authorities to recognize the pyromaniac as one mentally ill. When apprehended, these individuals frequently are tried in the courts as ordinary criminals and sentenced to prison terms. There can not be the slightest doubt but that such individuals should be kept in confinement, where they can do no harm. There is no more reason for punishing them in prison than there is for imprisoning others suffering from a different kind of mental illness.

There is evidence, moreover, that these cases will respond to treatment. Naturally, the results of such treatment should be carefully watched, and the dangerous cases not carelessly released to wreak further damage. Very interesting is the report of a man who had been committed to prison for setting a fire. A cure in his case was reported, following his assignment to the task of stoking the prison furnace. Here is a case of psychological adaptation, not deliberately planned, to be sure, but none the less effective.

The fact that a cure was effected in this way throws additional light not only upon the nature of the disturbance but also upon the possibilities of systematic treatment. Psychiatrists now recognize that the chronically insane form a comparatively small group of unfortunates. They now know how exquisitely fine are the adjustments of the mental organization, and the ease with which maladjustment takes place. Pyromaniacs fall definitely into this class of the mentally ill, and are therefore not properly to be considered as criminals and incarcerated solely for punishment, frightful and cowardly as their acts actually appear.

Pyromania, however, is by no means the only form of mental difficulty giving rise to incendiary fires. In the case of pyromania, fires are set because of the presence of morbid impulses. Hence the element of motive as ordinarily considered is entirely lacking. There are individuals, however, who, lacking in character, are known to react to situations that would not cause a reaction in a normal person. Likewise, a person suffering from one of the types of mental difficulty to which the legal term insan-

ity is applied may act upon a motive which to the normal person is devoid of all logic or reason.

Burnings from individuals of this type often are caused by young men from fourteen to sixteen. They are characterized by lack of emotion or affection, and often have cruel dispositions. When apprehended there is no evidence of sorrow for their acts, even in cases where there is a loss of life of human beings. Cases are recorded where boys of this type burned a barn and sat on the fence near by and watched the struggles of the animals. Sometimes the individual wishes to appear a hero to the community, or more frequently in the eyes of some girl. A case of this kind is recorded where a youth set fire to the barns belonging to the father of his sweetheart, then seriously injured himself in playing the rôle of hero. He was later committed as incurably insane.

A certain type of the hysteric often resorts to fires as a means of attracting attention to themselves. Oftentimes, to create a great excitement, he sets fire to some public building, such as a church, a school or other important edifice. When the fire is well under way, he breaks into prominence as its discoverer. Such an individual courts newspaper publicity and poses willingly for the press. Sometimes merely the craving for excitement prompts the act, and the individual responsible gets his satisfaction, not, as the pyromaniac, from seeing the flames, but rather from mingling in the crowd. This mental type is illustrated by the case of eight members of a fire department who were charged with originating the fires to which they responded. More than forty fires over a period of four years were attributed to the group. According to the report, they took their arrest as a joke and confessed responsibility for ten of the fires which had occurred within a few months just preceding.

When surroundings have become irksome, individuals lacking in mental strength have resorted to fire as a means of relief. Persons unwillingly retained in institutions have fired them, sometimes with the idea of creating a commotion and escaping, and at others motivated by the idea of revenge against society in general, or the institution in particular. Homesickness frequently has been the cause of such fires, and those responsible have frequently exhibited great skill and cunning in concealing their connection with the crime. Again, there are recorded cases where the despondent in difficult situations have caused fires, as when a discharged porter set fire to his uniform.

The problem is important for at least two reasons. While insurers bear the brunt of the losses from fire, they are nevertheless losses from a social point of view. What is destroyed is lost forever. If a study of the pathological types that are responsible for the setting of fires will aid in their apprehension and segregation, the effort may be well worth while from the standpoint of dollars and cents.

But aside from this there is another important feature to the problem. Arson is a serious crime. Under the common law it is a felony, and so punishable. Statute law has broadened the definition of arson to make it more inclusive, and continues to emphasize its seriousness through its retention among the crimes classed as felonies. With the increasing knowledge we have in the field of psychology and with the trend toward the utilization of this knowledge in the field of law, we are learning that the actual commission of an act does not of itself constitute a crime. In the cases of pathological arson it is not easy to decide where the element of responsibility ceases. There is no abrupt line of demarcation. Justice to the individual, however, involved in the setting of fires where the motive is not clear, demands a study of his case in the light of determining his responsibility, before he is placed upon trial for the offense.

# SCIENCE SERVICE RADIO TALKS

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# A POSSIBLE SOLUTION OF A MAYAN MYSTERY

By Dr. C. WYTHE COOKE

U. S. GEOLOGICAL SURVEY

THE explorer of an uninhabited land is likely to think of the region in which he travels as having always been in the same condition as that in which he finds it. He is likely to take it for granted that the same kinds of plants and animals have always lived there—the same birds of the air, the same beasts of the field, the same fishes and the same ubiquitous insects. He knows, of course, that species after species has appeared, reached its culmination and become extinct; but he assumes that most of the changes in fauna and flora took place long ago, in the dim geologic past.

But the earth is not dead or dormant. Geologic processes are going on all the time that may so alter the physical features of a region as to necessitate important changes in the distribution of the species of plants and animals that inhabit it. Most geologic processes act very slowly and inconspicuously, but their effects are cumulative. Now and then there is a critical time when the effects become suddenly apparent, just as when water, heated slowly, suddenly begins to boil when its temperature reaches the boiling-point.

Changes in the distribution of plants and animals may be brought about by geologic processes that act either within the earth or on its surface. For instance, strains and stresses within the earth may accumulate quietly until something breaks and the strained strata readjust themselves, causing an earthquake. Such crustal movements may suddenly raise or lower parts of the surface of the earth, thus interfering with the long-established drainage and causing the flooding of parts of the land or the emergence of the bed of the sea. Thus Reelfoot Lake in Tennessee came into existence in 1811 as a result of the New Madrid earthquake.

Also, the normal external processes of erosion and sedimentation, always going on, may produce rather rapid changes in the environment of living organisms. A lake receiving sand or mud from streams will gradually become shallower and shallower. The silting up may continue for centuries without perceptibly affecting the kinds of animals or plants that live around or in it. But in the course of time the lake will become so shallow that plants can take root on its bottom. Some kinds of fishes or mollusks or birds or insects will be favored by this change and will multiply; others necessarily will diminish in numbers. At last, its storage capacity diminished by silting and its loss of water increased by the transpiration of plants, the lake is likely to dry up now and then. This change proves fatal to many of its inhabitants, and others move away. Finally, the once open lake becomes a bog or swamp or meadow or arid plain, inhabited by a group of organisms very different from its original population.

This is what appears to have happened in the Peten district of Guatemala since the Maya Indians founded cities there two thousand years ago. To-day the ruins of their temples and palaces stand on hills of limestone overlooking great

logwood swamps or bajos—most uninviting sites for cities. The limestone uplands upon which the Mayan cities were built are quite habitable except for the lack of water. Like many other limestone regions they contain few perennial streams. Most of the rain-water runs into sink-holes, from which it rapidly drains away through underground channels. The only drinking water to be had is found in depressions in the ground that have become floored with an impervious layer of black mud. Water collects in these natural reservoirs (aguadas) in the rainy season, but many of them dry up completely before the next rains come. Some of the Mayan cities are without any present permanent source of water.

The bajos or logwood swamps appear to be large flat-bottomed lake basins filled with black clay. Most of the water that floods them during the rainy season quickly runs off through overflow outlets. For weeks after the flood water has receded they are almost impassable because of the deep sticky mud that covers them everywhere. Later in the year they become parched and dry. They are densely overgrown by thickets of thorny trees festooned with tangled vines. At all seasons the bajos are most unpleasant places to travel through. It is difficult to imagine why the ancient Mayas should have built their cities on the banks of bajos.

If the bajos were lakes when the cities were founded the mystery is solved, for there is no more beautiful or more suitable site for human habitation within the Peten district than the shores of a lake. Most of the present settlements stand beside lakes. The lakes furnish a plentiful and unfailing supply of water throughout the year; they teem with fishes, edible shell-fish and water-fowl; they serve as highways for the transportation of farm produce and other merchandise to the towns; they are centers of health-giving recreation; and they are very good to look upon. The word Peten in the Maya tongue means, indirectly, lake. It would be even more appropriate as the name of the district if the bajos, now logwood swamps, were still lakes, as some of them probably were when the country was first occupied.

The ruins of the ancient city of Uaxactun, now being explored by the Carnegie Institution of Washington, stand on hills overlooking Joventud Bajo, an extensive logwood swamp. In 1931 I suggested that this bajo might have been a lake when the city was founded; that soil washed off the cultivated fields into the lake, filled its basin and converted it into a bajo; and that this change may have been one of the interrelated causes that led to the abandonment of the city. With the hope of testing this hypothesis and finding whether the deposits in the bajo give a clue to its early history, an 18-foot pit was sunk in 1932 under the direction of Ledyard Smith, leader of the Carnegie expedition, at a place in the bajo about a quarter of a mile from the shore. Samples of the materials penetrated in this pit were examined microscopically at the Geological Survey by Dr. C. S. Ross.

From the surface to a depth of $6\frac{1}{3}$ feet, the bajo is underlain by a bed of tough black limy clay consisting of about two thirds clay and one third lime in the form of minute crystals of calcite. The black color is due to a little decomposed vegetable matter. Under the black bed is a deposit of light-gray marl composed of nearly equal parts of clay and lime, also in the form of minute crystals of calcite. Both beds evidently accumulated in water. The clay in each gradually settled from suspension, while the particles of calcite were crystallizing from solution and falling to the bottom.

A significant fact brought to light by the microscopic examination is that although the materials cut by the pit are essentially of the same qualitative com-

position from top to bottom, the relative proportions of clay and calcite are unlike in the upper and lower beds, the upper bed containing more clay and less calcite than the lower bed. Therefore, if we assume that the crystallization of calcite continued at a uniform rate, it is evident that the rate of deposition of clay was variable, being slow at first while the light-gray marl was accumulating and then suddenly speeding up to form the deposit of tough black clay. Keeping this in mind, we may interpret the early history of the Joventud Bajo at Uaxactun as follows:

At first there was a beautiful clear, deep lake. It was filled to overflowing during the rainy season and held an abundance of water throughout the year, although its level may have fallen below its outlet during the dry season. The water that flowed into it from the adjoining limestone uplands contained a little lime in solution and held a little finely divided clay in suspension. These materials were deposited on the bottom of the lake in the form of fresh-water marl, which accumulated very slowly until the lake was only about 6 feet deep a quarter of a mile from the shore. Then something happened that greatly increased the proportion of clay brought into the lake. The rate of deposition of clay was speeded up to one and a half times its previous rate, or perhaps even faster. A few centuries of silting at this accelerated rate may have completed the transition from lake to bajo. The cause of the sudden increase in the rate of deposition of clay may have been the beginning of cultivation of the soil by newly arrived inhabitants. Some soil erosion is always going on, even beneath a virgin forest, but the rate is slow. The clearing of the forest would have permitted the tropical downpours of rain to beat upon the ground and to wash away the clayey soil of the uplands into the lakes.

Let us inquire what effects the gradual transition from lake to bajo would have had upon the human inhabitants of Uaxactun. Most important, perhaps, is the effect on the water supply. While the lake was still deep there was never any scarcity of water, and natural agencies probably kept it reasonably pure; but as it became shallower and shallower the volume of water in it became less and less and it became more and more subject to pollution. The women and children had to wade farther and farther through the sticky mud in order to reach water deep enough to fill their jugs; and finally, at the height of some dry season, there was no water to be had. Perhaps before this catastrophe took place the prudent Mayas may have thrown up dams to impound some of the flood water in artificial reservoirs, or perhaps they may have stored enough water in cisterns to supply their needs.

Then there is the effect on the food supply. No one knows to what extent the ancient Mayas may have supplemented their mainly vegetable diet with fish, but it seems hardly likely that they would have totally neglected such a valuable natural resource. Their descendants eat fish when they can get it, and they also make use of a large edible fresh-water snail. This snail, an Ampullaria, unlike the fishes, survived the filling up of the lake and still lives in the bajo, sealing itself in its shell at the beginning of the dry season and patiently waiting for the floods to release it. The lake at Uaxactun may also have swarmed with water fowl, some of which undoubtedly would have found their way into the cooking pots of the Mayas, but when the bed of the lake became baked and dry the flocks of birds must have sought other feeding grounds.

Next let us consider the effect on commerce. As long as the lake was deep enough to float a canoe, a brisk commerce was doubtless carried on upon its waters. Cargoes of corn and papayas and other fruits and vegetables were

taken from the farms along its shores to the city, and boatloads of pottery and other manufactured articles may have come from a distance for sale in the market place. Gradually navigation on the lake became more and more difficult and at times of drought ceased altogether. Finally no boats could navigate the shallow waters. Thenceforth all imported produce and merchandise had to be carried to town on the backs of plodding Indians.

The silting up of the lake must have had an important effect on the health and comfort of the people. The pollution of the water supply has already been mentioned. Stagnation of the water and the scarcity of fishes and other natural enemies must have permitted an enormous increase in the number of mosquitoes. Infectious diseases spread by bad water and insects may have taken a heavy toll from the population.

Man, even civilized man, is little less immune than other animals to changes in his environment. When living conditions in a region get too uncomfortable he moves away. The once populous city of Uaxactun is now totally uninhabited and lies buried deep in the jungle. The silence of its ruins is broken only by the howl of the monkey, the shriek of the macaw, or the crash of the falling tree. Even the lapping of the waves on the shores of the lake is now stilled, and to the cause of that stilling may perhaps be attributed the abandonment of the city by its human population.

# MAN: DUST OR DEITY?

By Dr. MADISON BENTLEY
SAGE PROFESSOR OF PSYCHOLOGY, CORNELL UNIVERSITY

Everything has its market price. For food and clothing we give money; for money we give our toil; kindness we repay with kindness, and to evil deeds we mete out suitable punishments. Everywhere purchase-price, price-tags, estimations of value. To be sure, the markets rise and fall, prices move upward and downward; but upon most of their possessions men manage, at any given time, to come to an understanding. Stocks and bonds, butter and eggs, dollars and pounds, lands and cattle, all have their daily quotations which advertise to you their daily values, whether you sit at this minute in Nebraska or Alabama, in Boston or Los Angeles.

But upon his own value, man has never come to a fixed conclusion. His uncertainty is obviously not due to his lack of interest. For ages he has been deeply concerned over his own proper place in the scale of earthly and celestial beings. Here he has been of two contrary minds. In one mood man calls himself a god, a spirit, the lord of creation, and counts himself only a little lower than the angels. In another mood he is a worm, a disease of the dust, a helpless infant crying in the night; he avers that he was conceived of sin, is by nature weak and vile, prone to evil as the sparks fly upward.

Are these extremes of self-valuation correct? Does man properly stand both at the top and at the bottom of the scale, fluctuating from one extremity to the other, according as his mood is of self-approval or of self-condemnation? One circumstance makes us distrustful of his double self-rating. Man's human estimations usually depend upon whether the valuer is thinking of himself or of his enemy, of his own province or of some other, of his own race or of an alien people. Men are notoriously kind to their own kind and scornful of strangers. Where can you find a race,

people or culture which does not hold itself higher than it holds all other races or peoples? A white man reared in South Carolina confessed to me that he was genuinely shocked to discover that black people contain red blood like his own. Orientals despise the upstart Westerner, whites regard the brown-skin as a savage, blacks in their own undisputed domain look down upon whites and yellows. Greek and barbarian, Latin and Nordic, German and Jew, Yankee and mountaineer, Hindu and Parsee—each is arrogant and each disparages the other. Race, color, religion, economic rivalry, unlikeness of custom and many other means of human division, all tend to set on high one's own kind and to depreciate all others.

Here operates a principle of behavior that is both fundamental and momentous. The conduct of all social animals is determined by the pattern of the group as well as by the nature of the individual itself. The provincial abroad can not act naturally. He is constrained and unfriendly. The "outside" pattern does not conform to his own provincial manners. He clings to his comfortable habit, while he despises the disconcerting conduct of the foreigner. To be just in their human values, men have to surmount this inveterate tendency, the tendency to rate high their own kind and to rate low the stranger and the alien.

But failure here is disastrous; and the more tribes, nations and races commingle, each living with all and each valuing all, the more disastrous it is. We like to think that civilization has made men objective and tolerant. But just as we flatter ourselves that it has made men of one kin, some race, religion or people rises to assert its purity or its superiority. May we hope that such a primitive and barbarous discrimination of men will presently be outlawed by a more enlightened and self-respecting judgment!

A wholesome corrective to this distortion of racial and tribal values is afforded by a wider perspective, by a view which places all human kinds together against a common background of the universe. Imagine yourself removed from the earth and looking out upon the planets with the eye of the sun. Now man and all his works and concerns shrink in the distance. His own little world spins, a grain of sand, among a group of tiny planets. Here the blazing sun is central, and man himself becomes an imagined fleck of dust.

The perspective becomes still broader and clearer when we forsake our great sun and fly to the very limits of our whole stellar group or galaxy. Now our sun is himself lost among a million suns, some of them a million times his volume. Just where our local lord of day and night stands among this great galactic host, no one is certain; although it is agreed that he (and we) are so far from a central position that thousands of years of travel, moving with the unattainable speed of light, would be required to bring him into the doubtful eminence of Central Ruler in the galaxy. Should we still retain a delusory idea of the cosmic importance of earth, of genus *homo*, of a chosen race, of a "pure stock" or of a vaunting dictator, let us project ourselves still further from the large boundaries of our galaxy, proceed for a million light-years through vacuous space and approach another stellar galaxy. This may be the famous nebula of Andromeda, as roomy at least as our own galaxy. But Andromeda is itself but a way-station on a journey which might go on for fifty, sixty or eighty million years and still not reach the most distant outposts that signal to our earth, to our most powerful microscopes, and ultimately to the seeing eye of man.

The mere bigness of this celestial cosmos, where unnumbered galaxies float in unbounded interspaces, tempts us to forget that puny man exists. At least as a

space-filler man would seem to be negligible. Even his breath-taking flights in airplane and racing-car give a comic futility to the spaciousness of this little earth. Though he whirl round and round his tiny ball in minutes or seconds, the event has no significance for his tolerant sun, and its human impressiveness is quite lost on the galaxy and on the other cosmic masses.

But mere bigness is not everything. To the recipe of man's composition went about a quarter of all the elementary substances found in the entire universe; carbon, hydrogen, oxygen, iron, nitrogen and a score of other chemical elements. He himself is a fair sample of the entire cosmos. The make-up of his body is—we may believe—far more complicated than that of any star or galaxy of stars.

When the mountain and the squirrel had a quarrel, the mountain called the squirrel "Little Prig." The squirrel replied, "If I can not carry forests on my back, neither can you crack a nut." Possibly man can, in spite of his spatial insignificance, sustain his value to himself, if not to his universe, by some great feat of nut-cracking. That would not, to be sure, sanction his contempt for foreigners and his persecution of neighbors, but it might restore his self-respect for his human kind.

Now those very men of science who have revealed the trivial character of our tiny earth and who have set light-years against the modest span of man's life are inclined just now to offset this contrast of the big and the little with quite a different kind of perspective. Physics and astronomy now tend to discredit their older mechanical notions of mass, of space and of independent motion in a given body, and they even throw doubt upon the utility of the concept of matter in a description of the world. The general result of this view of things is to replace the common scenery and activity of the universe, as we naïve earth-dwellers regard it, by mathematical symbols and formulas, by abstract concepts of quanta, electrons and wave-motions.

But who made the symbols and formulas? Why man! If man has, then, created a symbolic and abstract world, he may after all have displayed miraculous powers as a cracker of giant nuts. This possibility has so impressed the physicist that he has been led to conjecture that something like the mind of man, not matter, is the most real and the most fundamental thing in the universe. Matter he is ready to discard as illusory. Mind then comes to the top, and we find many new books on the nature of the physical world and of the mysterious universe winding up in discussions of mind-stuff, freedom of the will, and the unequalled powers of man.

Do you not see that this strange turn of affairs in the physical sciences has really put man in a new position in the cosmos? From being a mere observer of a great, self-sufficient and self-running machine, he now appears as the fountain-source of the only real stuff in the whole wide world, namely, the fountain-source of mind. No longer, therefore, is man a mere mote in a sunbeam of universal energy, a microscopic speck in a forgotten crevice of a negligible corner of existence. He is no longer merely the little end of nothing whittled to a point. He is (since his body disappears with all the other material lumber of the place) the only real stuff. He is mind. If man is not therefore a real and creative deity, you will agree with me that the physicists would make him much nearer deity than dust.

Now I do not believe that the thing is quite so simple as all that. We should not be too hasty in agreeing with the physicist when he declares "Not matter, therefore mind." From being highly sophisticated in his own field he suddenly becomes very naïve. He is much more at home among his physical facts than he is among biological and psychological facts. In his bewilderment at the

loss of his old notions and categories, he has taken refuge in a very old and fairly musty philosophy of existence. Having lost matter, he clutches desperately at mind. In reading Eddington, Jeans and other writers of the "new idealism of science," one gains the impression that these men are, for the moment, at the end of their scientific tether and are perhaps unwise to try, while in a state of bewilderment, to make a decision upon the universe and upon man's place in it.

At any rate, I doubt whether we should too hastily drag dusty man from his obscure cranny and apotheosize him as thinker, creator and universal essence. Nor need we agree with the older theories of science, which saw in man only a passive observer of the great cosmic parade. Man is, as we actually know him, both trifling and great, both puny and pompous, worm-like and god-like, mean and magnanimous, foolish and wise. If he can not grow forests on his back, engender earthquakes, sway the sun and moon in their courses and flash—a bright meteor—across the sky, he can and does weigh his own earth and many stars, make earth fertile and habitable, invent tools and build microscopes, stare into the eye of a million conglomerate suns, compute celestial times and distances, and write about all these marvelous things in strange hieroglyphics for his grandchildren to read and to revise.

And that, my fellow men and women sitting with puzzled brows throughout the whole United States, is—so far as we know—more than any planet, star, galaxy or spiral nebula has ever done. Man may be little, but he is, in his way, also terribly clever. Though he can not alter the eternal course of the galaxies, he can pry into their secrets with a vast and intelligent curiosity and he can move in imagination through the endless aisles of space. If not a god, at least no ordinary worm of the dust!

# BETWEEN THE STARS

By Professor OTTO STRUVE

DIRECTOR OF THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO

VISITORS to an astronomical observatory almost invariably ask the question: "How far into space can you see with your large telescopes?" The answer is not as simple as it might appear, because the extent of our vision is greatly reduced during the daytime, while at night it reaches far out into space among the stars and beyond the confines of the Milky Way system of our galaxy. Even at night our vision is limited, not only by the insufficiency of light from distant objects, but also by a faint glow which covers the night sky and makes it impossible for us to observe or photograph the most distant stars with powerful telescopes and sensitive photographic plates.

Let us see why our vision is so much impaired during the day. Every one has noticed that terrestrial objects, such as mountains, a few miles away, have a bluish and indistinct appearance. Even directly above us, on a perfectly clear day, an aeroplane looks hazy and indistinct at an elevation of a few thousand feet. The explanation of this lies in an interesting phenomenon known as scattering of light, with which every driver of a car has had practical experience. When the sun beats down upon a dusty windshield the driver's vision is impaired and the road ahead is scarcely visible. But if the sun disappears behind a tall building or a cloud passes over it his vision is at once improved. He is no longer aware of the haze produced by the dust on the windshield, and distant objects stand out almost as

clearly as if he were looking through a clean piece of glass. This simple observation proves that the dust on the windshield does not act as an opaque screen, for if it did it would reduce one's vision in the shade as well as in the sun. What happens is that when the light from the sun strikes the dust particles a small fraction of it is scattered in all directions and some of it enters the eye of the observer and falls upon the same part of the retina upon which is focused the image of the road. This reduces the contrast and makes the outlines of the object indistinct. As soon, however, as the rays of the sun are shut off from the dust there is no scattering of light and consequently no reduction in contrast.

This is just what happens when one looks out into space on a clear day. The earth in its motion through space is surrounded by a screen of very small particles. Every molecule of air and every particle of dust scatters some sunlight and throws it into the eye of the observer where it overlaps the images of stars and renders them indistinct. Just as soon, however, as the sun disappears below the horizon at sunset, the scattering effect is reduced and vision is improved. Here again the particles of air and dust do not act as a screen of opaque matter, and when the effect of scattering is removed the observer is at once able to distinguish the light of the stars and nebulae, so that, instead of noticing an appreciable reduction in vision at an elevation of a few thousand feet, he is now able to distinguish objects which are far away from the Solar System.

The brighter stars become visible to the unaided eye; then as the sun moves lower and lower under the horizon fainter objects appear, and finally, when the sun has reached a point about 18° below the horizon we are able to distinguish distant galaxies which are so far away that light traveling at the rate of 186,000 miles per second has been on its way for millions of years. The sky has now reached a constant amount of faint illumination which it retains throughout the remainder of the night.

The background of the night sky is by no means devoid of all light. There are the stars which send their rays in all directions, and some of the starlight is scattered by particles of air and dust in our atmosphere. Astronomers have computed that this source of scattering is not appreciable, so that even our most accurate instruments of measurement would fail to record it. Why, then, is the night sky not black between the stars? On a clear moonless night the sky is faintly luminous, as every one can easily prove to himself. In fact, there is so much light that trees and other objects are clearly outlined as black shadows on the grayish background of the sky.

The ratio of the amount of light coming from the night sky to that coming from an equal area of the daylight sky can be determined by a simple photographic procedure. If we expose a plate, in an ordinary camera, to the blue sky during the day, with the shutter set at 1/1000 of a second, upon developing the plate we will find that the sensitive film is uniformly darkened. Then, if we point the same camera at the night sky and gauge the exposure time by trial so as to obtain the same degree of blackening on the plate, we find that it would take about ten hours to get the required result. The ratio of the brightness of day sky to night sky will be in proportion to the two exposure times. Ten hours divided by 1/1000 of a second gives approximately 40 million times.

The source of the illumination of the background of the night sky has not yet been completely solved. We know from the work of the Lowell Observatory at Flagstaff, Arizona, that a part of it is produced in our own atmosphere, though the physical phenomenon giving rise to this part is not scattering of starlight or of sunlight within our atmosphere. The

spectroscope has revealed that this atmospheric illumination of the night sky consists of rays of light of certain distinct colors, not of a mixture of all colors of the spectrum. It is possible that the so-called cosmic rays, so thoroughly investigated in recent years by Dr. Millikan, of Pasadena, and by Dr. Compton, of the University of Chicago, when hitting the molecules of the air cause them to emit feeble rays of light which are observed by us as a general illumination of the night sky.

However, astronomers believe that the spaces between the stars are not absolutely empty. The spectroscope is the instrument which 28 years ago proved that atoms of calcium vapor were traveling in all directions through interstellar space and since then atoms of other elements have been discovered to be present in all parts of our galaxy. The question arises whether starlight is scattered by these interstellar atoms, thus adding to the illumination of the background of the night sky, as the scattering atoms of our own atmosphere add to the illumination of the day sky. The answer depends upon whether there are enough atoms in space. Careful measurements have been made at the Yerkes Observatory of the amount of gaseous matter between the stars. The result is startling. Imagine a cubic inch of ordinary air drawn out into a column long enough to reach one of the more distant stars of the universe. To be exact, imagine that the column is 15,000 light years long, retaining of course its cross-section of 1 square inch. Let all the atoms which formerly occupied our cubic inch of air be spread uniformly throughout the column. The resulting density of matter will be that of interstellar space.

It is not probable that this small amount of gas would scatter enough starlight to add appreciably to the illumination of the sky. There remains the possibility that in addition to gaseous atoms interstellar space may contain particles of dust. Numerous observations have been made to prove whether such dust actually exists. It was found that distant stars are usually redder in color than those which are not so far away. Now it happens to be one of the properties of scattering by very small particles that a beam of light passing through the dust is reddened, while the scattered light is made bluer. Thus the scattered sunlight appears as the blue of the daylight sky; every one has noticed this effect: when the sun is near the horizon it appears brilliantly red, while the sky overhead is blue.

The fact that distant stars are redder than near-by ones might simply mean that the light from distant stars passes through more interstellar dust than does the light from the closer stars. The transmitted beam of starlight is depleted in violet and blue colors, and remains rich in red light. The scattered radiation, which comes to us as the general illumination of the night sky, must consequently be blue in color. Observations are now being planned at the Yerkes Observatory to determine the color of the night sky. Our visual sensations give us no information concerning this point, because the human eye does not distinguish the colors of very faint objects. In the meantime we may consider the hypothesis of interstellar dust as probable, though not as definitely established. A German astronomer at the University of Breslau has recently computed the number of dust particles per cubic centimeter of space required to produce the observed amount of reddening. His conclusion is that there should be one dust particle for every 500 cubic centimeters. I suppose this would indicate that our galaxy is a dusty place in which to live!

# THE SCRIPPS INSTITUTION PIER AS A MARINE OBSERVATORY

By Professor WINFRED EMORY ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA

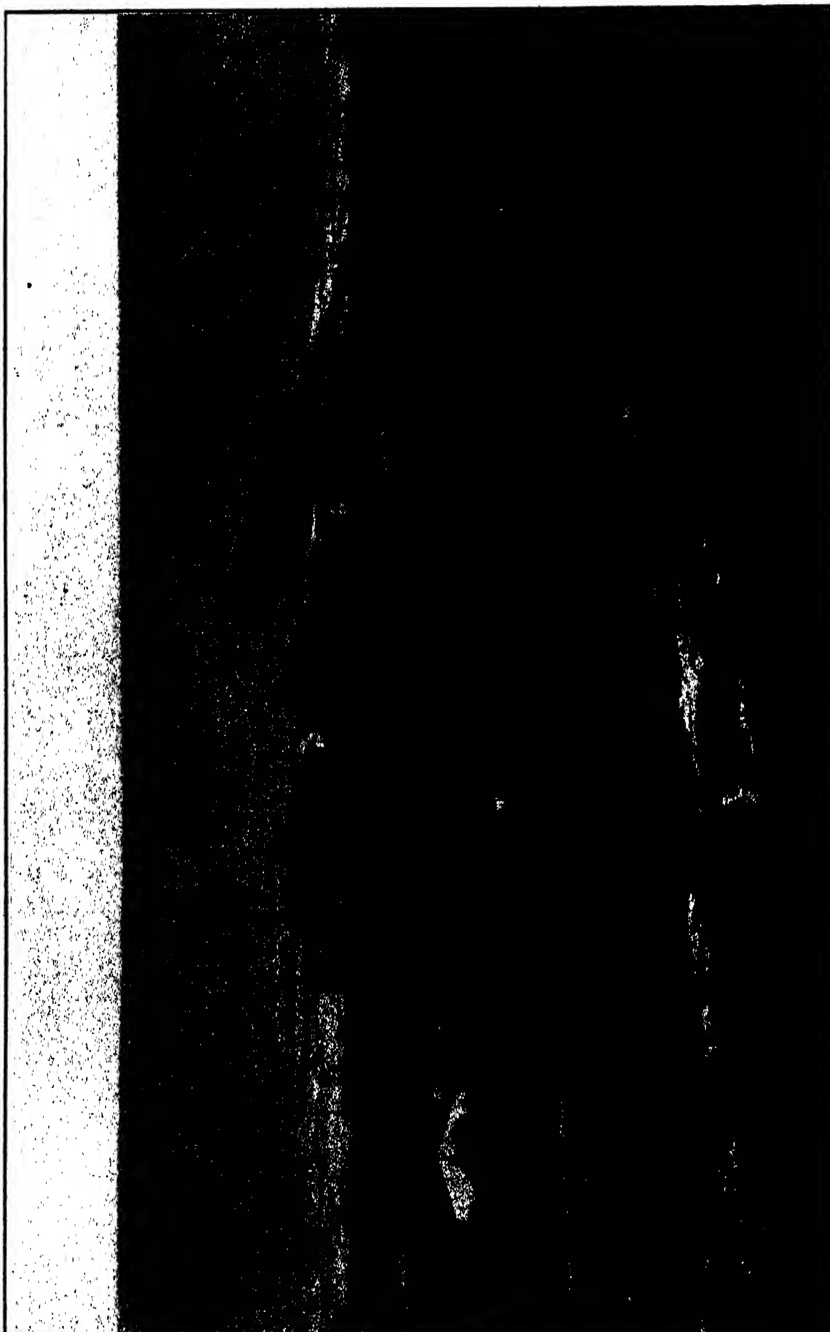
THE pier of the Scripps Institution of Oceanography of the University of California at La Jolla, California, extends into the open ocean to a thousand feet from shore. If a structure similarly extended a thousand feet into the air, it would be furnished with equipment of many kinds at fabulous cost and used for making observations in astronomy or meteorology with a corps of expert observers in *constant* attendance. As matters stand the institution pier is a partially dilapidated structure, carrying *relatively* little equipment and visited only for short periods daily for routine observations by a few employees, although much less is known positively about the ocean than is known about the solar or sidereal systems or about the ocean of air.

Aside from the records of a U. S. Coast and Geodetic Survey tide gauge and of a water thermograph, no continuous observations of any kind are made at the pier, other physical as well as the chemical and biological data being obtained from observations rarely more frequent than once in twenty-four hours. Even so, it seems probable that the Scripps Institution pier is unique amongst piers all over the world in respect to the number of different ways in which it is used for scientific investigation of the sea.

For some strange reason, direct and continuous observation which is considered essential for investigations in both astronomy and meteorology seems to be regarded as a matter of indifference for oceanography, which presents problems more intricate and difficult than either of them. Indeed the attitude of the scientific élite appears to be that the ocean can be studied most satisfyingly in one of three ways: First, by chasing across or around it with a big expedition taking transient observations at intervals of some hundreds of miles; second, by ignoring it altogether and retiring into a laboratory to perform "controlled experiments" from which all possibility of ocean influence has been removed; third, by conducting research in some science related to or connected with oceanography under the expectation that familiarity with that science will yield some knowledge of oceanography traceable through the connection.

Like any other of the common run of scientific men, I hold to the view that the way to learn about anything is to go to it directly, get as much contact with it as possible, and study it as much as possible in the conditions of its natural existence. That accounts, in part, for my own interest in observation and in the pier as an observatory. However, it is probably true that a still more important part in stimulating and holding my interest is to be found in the infinite number of fascinating problems suggested by conditions and occurrences observed from the pier, and in the surprisingly striking single features which may appear at any moment.

For the present I shall neglect the results of my routine experiences in use of the pier for the sake of telling about some of the surprises which have come to me in the fifteen years since I first began to visit it regularly and frequently. In that time I have visited the Scripps Institution pier five or six thousand times, usually remaining on it not more than



THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, AND ITS PIER EXTENDING A THOUSAND FEET INTO THE OPEN OCEAN

one hour, or the time necessary for making my collections of microscopic or sedentary plants and animals. Presumably an observer in constant attendance might have seen a much larger number of surprising things than I have seen in the limited time.

For pure astonishment, I think I was never more affected than I was at the time that I idly glanced at a pelican in gliding flight about fifty feet above the water and noticed something like a three-foot length of garden hose drop and hang dangling loosely from between his shoulders. In a moment I was little less astonished when I saw him reach a foot forward and scratch the middle of what I then recognized as his head and neck hanging directly downward. After relieving the local irritation the head was lifted to the usual position above his back and the bird glided calmly onward with never a hitch or halt in his steady progress.

The California brown pelicans have also presented to me two less exciting puzzles, one of which I think I have partly solved. The latter is the puzzle of the half turn in diving. It took about six years of observation to satisfy myself on that point, but I finally became convinced that a bird plunging into the water while headed south makes a side sweep of his pouch just after striking the surface, and that this move to net his fish brings him up facing north as he rises above water again. In one case I saw the pouch distended like a football just after a dive at the end of the pier and on two other occasions I have seen it partly distended. The other pelican puzzle has never approached a satisfactory solution. It is as to why a pelican should try to perch on the wire (smaller than a lead pencil) stretched along above the pier rail. I have seen this kind of perching tried several times, although the pelican is not a perching bird and has no equipment for holding to a slender perch. In one case a pelican persisted in trying for a period of about twenty minutes. He was close to the pump house, from the window of which I chanced to notice him alight, so I was able to time him and to watch the details of his performance. In order to balance on the wire he had to use his wings. Every few seconds after getting a standing balance he would try to fold them and settle into perching position. This would cause him to lose balance and teeter back and forth with wings gently flapping until he was balanced again. I have often wondered if it amused him to see if he could perform the feat of perching on the wire in spite of his lack of fitness for it.

Another interesting thing about pelican behavior is his series of efforts to keep a gull from stealing his catch after a dive. Often when he comes to the surface and raises his head to let the water drain from his beak a gull is at his side picking at the fish seen between the edges. The pelican immediately starts paddling with one foot to swing in a short circle, the gull paddling desperately to keep up, and so they go until the water has drained and the pelican is able to throw his head up to swallow the catch. Sometimes two or more gulls combine and by getting on both sides of the pelican they prevent his circling movement. In that case they are likely to get some of his catch by snatching it through the slit at the edges of the beak.

Only a little, if any, less astounding than the pelican neck scratching in flight was my only acquaintance with a thresher shark. I was making my plankton collection one morning when a noise attracted my attention to the water a little way from the pier. I turned too late to see anything but the agitated surface, but in a moment later there was a splash and flurry near the same spot in the midst of which something like a human arm seemed to be thrust above the surface and to disappear too quickly for

me to get any clear idea of its form and size. I was still wondering about this peculiar exhibition when I thought I saw a "sand shark" about five feet long swimming rapidly toward the pier at the surface of the water about fifty yards away. A little later I could see that it was chasing a fish of about a foot in length. While watching the chase I saw the shark dart past the side of its victim and then make the water boil with a whip-lash stroke of its tail at the little fish. I then saw that it was a thresher shark and knew that the arm-like apparition above the water had been its tail thrown through the air in making a stroke. The small fish seemed to be badly dazed by the fierce stroke I saw so clearly and was swimming less rapidly in a crooked course when another stroke of the thresher's tail stunned it and it turned over on its back, struggling feebly. The shark rushed at it with open jaws, but just before seizing it he appeared to be frightened by the drip of the water from my collecting apparatus only a few feet away. So he turned and swam off. The injured fish floated helplessly for a while, but it finally revived and swam slowly away.

An auklet and a flounder were the actors in another scene so strange that I could hardly believe my eyes. I was just going on to the pier one quiet morning and had got beyond the surf when I noticed a Cassin auklet swimming toward the pier on the south side. I stepped to the rail to watch the little fellow paddle out of sight and I was just in time to see him rise off the water in a great splash and flutter and dart off in headlong terror. In the instant that he cleared the water a large flounder leaped through the air in pursuit and its snapping jaws missed the bird only by inches. I have known about birds catching fish most of my life, but this is my only observation of a fish trying to catch a bird.

On a few other occasions auklets have participated in interesting performances. At several different times I have watched Cassin auklets swimming under water, using their wings entirely for the swimming and their feet and tails for steering and control. Once or twice these little fellows have given excellent exhibitions in chasing small fish about the pier, but the best I ever saw was given by a Rhinoceros auklet at the end of the pier one morning when the water was a little rough. He was chasing fish around the piling and sometimes I was sure that he was going to be crushed as he darted into the swirl of a passing wave around a pile with wings full spread and beating as though in air. But he always came out all right, and he caught fish, too.

Some years ago, when sardines were more abundant near the pier, I often saw loons working on a school, but I never saw a fish caught by one of them. If the loon started for them at the side of the school a lane opened through it with sardines on both sides apparently at exactly equal distances from him. If he dived and came up from below the school an exact circle would be formed by the fish with the loon at the precise center. It seemed that so many fish were at the same distance from him in different directions that the bird could not decide which individual to chase. He could swim faster than any one of them, although he used his feet only in swimming.

Although I did not see it myself, it is surely appropriate to mention in this connection the killing of an octopus by a sea-lion, observed from the pier by Professor W. R. Coe, of Yale University, some years ago. The octopus was too large to be killed and swallowed easily, and the sea-lion had to spend considerable time in getting it disabled. Whenever he seized it its arms would twine about his head and he would have to shake himself vigorously in order to dislodge it. At every opportunity he

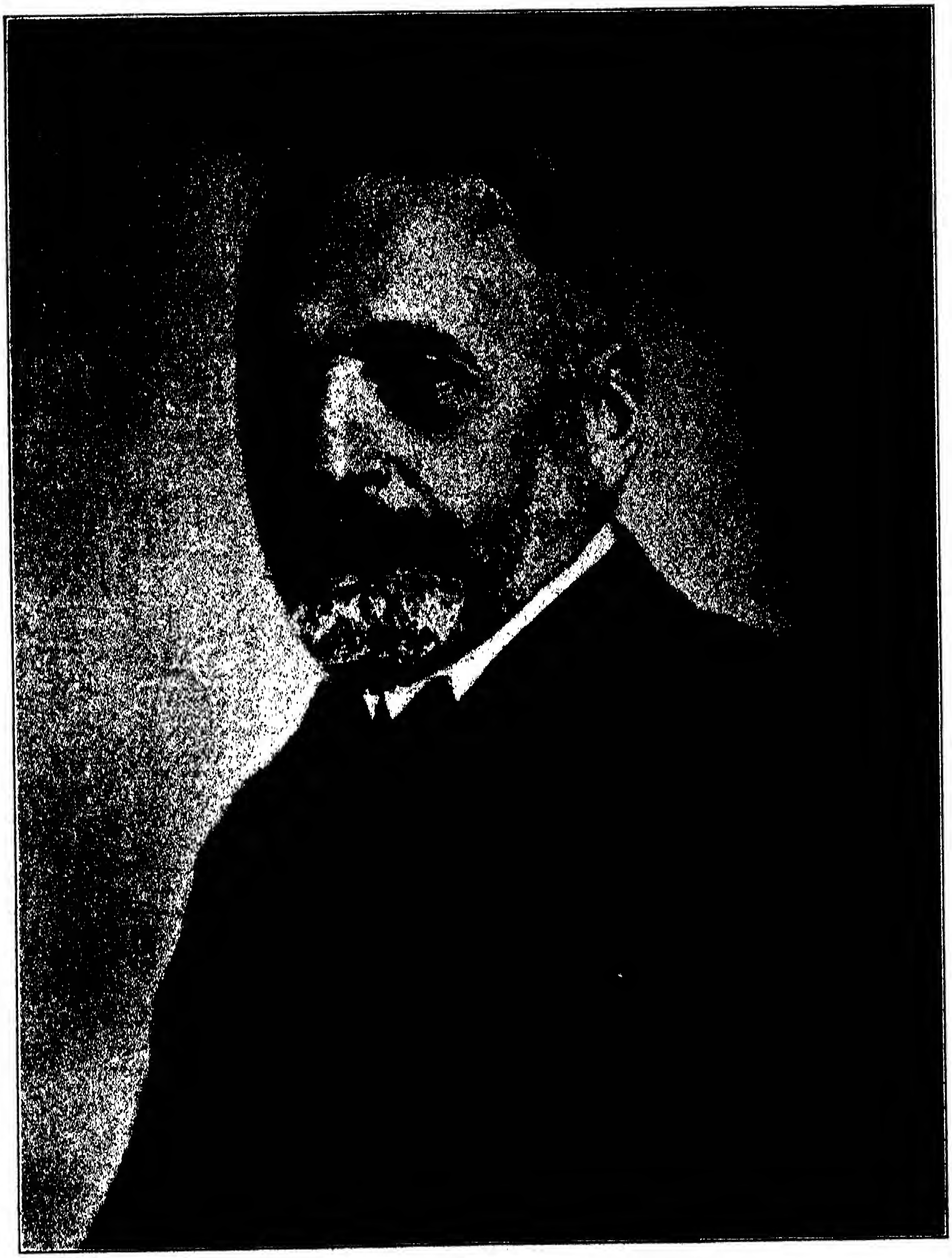
would shake it and toss it into the air until it was finally disabled to an extent that ended resistance.

Certain other rare sights have been less exciting because developing more slowly or because of being less conspicuous. Neither sea-lions nor porpoises have been abundant in recent years. About ten years ago two herds of sea-lions could be seen every morning near the pier for several days, each herd consisting of about fifty individuals. Some years ago porpoises frequently came near the pier, and I once saw a school which I estimated as covering about one fourth of a square mile in area. It paraded up and down seaward from the pier for hours. Since then I do not recall seeing more than four or five porpoises at a time and that rarely.

About ten years ago siphonophores were seen drifting past the end of the pier in great abundance for one day and in considerable numbers on two other days. I have noticed a few specimens at only one or two other times. About 1920 I saw a school of mackerel pass the end of the pier one morning. The fish were swimming all in the same direction and as close together as possible and the school extended as far as I could see from the pier. It took about a half hour to pass. I once saw "sand sharks" so thick alongside the pier that I could not have thrown in a line without hitting one. I have rarely seen more than four or five at a time on other occasions. In 1924 the dinoflagellate *Prorocentrum micans* was so abundant near the pier for a week or more that the water was colored reddish brown. It is the only case of "red water" in sight of the pier in the fifteen years of my connection with the institution.

Some of the things I have mentioned seem remarkable or important to me because they were striking performances of individual animals, showing in the first place that it is practically not possible to imagine what an individual animal can or will do or how it will do it, and in the second place that one can only get acquainted with nature by actual contact and observation. Others seem remarkable and important because they show that conditions in the ocean are constantly changing, sometimes allowing populations to exist in what we call a normal state or in equilibrium, and sometimes changing so that strange populations come into prominence or even gain a temporary ascendancy.

The problems of individual performance which I have noted are most fascinating to me, but the problems of shifts or of maintenance of populations in particular locations or regions are the ones which seem most important or at least most urgent. At any rate, I hope that I have helped to show that a pier is an important observatory and that piers deserve more use as such than they have ever had.



DR. RICHARD WILLSTÄTTER

# THE PROGRESS OF SCIENCE

## RICHARD WILLSTÄTTER, WILLARD GIBBS MEDALIST FOR 1933

Richard Willstätter was born in 1872 at Karlsruhe and there received his early training, which was continued at Nürnberg and at Munich. At Munich he was known to his laboratory mates as the "little Beilstein" because of his phenomenal grasp of organic chemistry. He soon attracted the attention of Adolph von Baeyer, who made him assistant, privat-dozent and then extraordinary professor and head of the organic division.

Willstätter's first independent work resulted in the solution of the structures of atropine and cocaine and other physiologically active materials, including sparteine and related alkaloids. His first private assistant was an American, C. S. Hollander. His work in this period laid the basis for all modern studies in synthetic local anesthetics which lack the habit-forming properties of cocaine.

In 1902, at the age of 30, he was called to Zurich where he started work on the chlorophyll problem with the aid of a large group of students and assistants from all parts of the world. During his years in Switzerland, he made more progress toward unraveling the structure of chlorophyll than had all previous workers. He showed conclusively that the parent substance of chlorophyll is the same as the parent substance of hemoglobin. He thus showed that nature had used the same fundamental material, etioporphyrin, to make the green coloring matter of plants and the red coloring matter of blood, by combination in one case with magnesium and in the other with iron; to give substances which, in one case, convert carbon dioxide to oxygen and complex organic material and in the other carry oxygen to living animal tissues. These studies laid the foundation of the work of Hans Fischer and of Conant.

During his studies of chlorophyll, Willstätter became interested in the other coloring matters of plants and opened up the fields so brilliantly developed in the carotinoids by Karrer and by Richard Kuhn and in the anthocyanines by Robert Robinson.

In 1912, Willstätter became director of organic research at the Kaiser-Wilhelm Institut. Here he carried out his most important studies on the coloring matter of flowers. Here again he showed the surprising unity of nature. For instance, the blue of the cornflower and the red of the rose were shown to be caused by the same pigment, cyanidine, in acidic and basic media, respectively.

At the outbreak of the world war, Willstätter took up aviation but was instructed to continue his laboratory studies. Although he worked on war problems such as the use of "hexa" in gas masks, most of his efforts continued in the field of the flower colors.

In 1915, he was called back to Munich on the death of his first teacher, von Baeyer. In 1918, Willstätter started his researches on enzymes, the organic catalysts responsible for life processes. In this tremendously difficult field, he has laid solid foundations which have been developed by a small but active group under his leadership at the Laboratory of the Bavarian Academy of Science since 1925 and by several of his former students, among whom Waldschmidt-Leitz, of Prague, is preeminent.

Willstätter is the holder of many scientific honors. In addition to the Nobel Prize in chemistry, he has received the Faraday Medal, the Prussian Order pour le Merite and honorary degrees from many universities. He has visited the United States in 1895 and 1927. Among his former students who have become prominent in America are Roger Adams, E. K. Bolton, A. S. Burdick, Michael Heidelberger, C. S. Hollander, C. D. Lowry, Jr., and Jean Piccard.

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## HYDRO-ELECTRIC DEVELOPMENTS IN SWITZERLAND

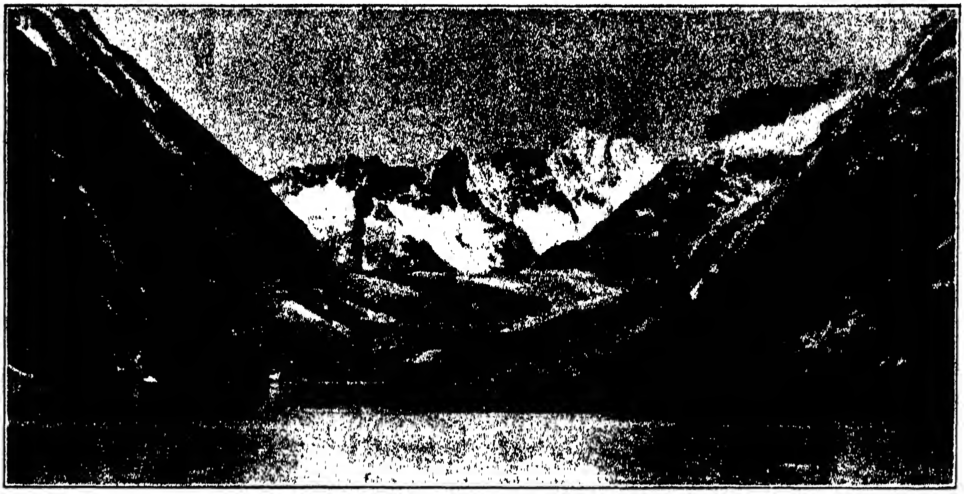
In Switzerland, the country of the "white coal," as electricity is called there, another important step in the electrification of the country has been accomplished by the construction of a large seasonal storage plant, the Oberhasli Hydro-Electric Development, above Meiringen in the Bernese Oberland. Construction work on the first step of this huge project was completed recently and the Handeck Generating Station turned over to regular operation last fall.

GRIMSEL LAKE IN THE BERNESE OBERLAND

IT HAS BEEN CREATED BY THE CONSTRUCTION OF TWO DAMS, THE SEEUFEREGG DAM IN THE FOREGROUND AND THE SPITALLAMM DAM IN THE CENTER OF THE PICTURE.

The entire development utilizes the precipitations as well as the melting water of a total area of forty-three square miles, formed mostly by the glaciers of the picturesque "Bernese Oberland." Since 95 per cent. of the annual natural flow of water takes place during the six summer months, it was essential to create huge storage basins, to have the water collected during the summer available for carrying the high peak of power demand during the winter. Nature offered very favorable conditions, and engineers found it practical to create two large artificial lakes. The larger, Grimsel Lake (Grimselsee), has a storage capacity of three and a half billion cubic feet, while the smaller, Gelmer Lake (Gelmersee), has a capacity about one seventh as great. The total storage capacity of these two lakes corresponds to 230 million kilowatt-hours.

The Grimsel Lake has a surface of twenty-seven million square feet and a total length of approximately three



MOUNTAINS IN THE BERNESE OBERLAND
WITH GRIMSEL LAKE IN THE FOREGROUND.

miles. It is formed by two dams, the Seeuferegg Dam and the Spitallamm Dam. The former is the outstanding feature of the entire development, due to its dimensions, and only those familiar with the climatic conditions at an altitude of 6,300 feet above sea-level know how to appreciate the difficulties under which construction work was done. Due to the extreme severity of the winter, work could progress only during a few months a year.

The following figures may give an idea of the size of the Spitallamm Dam,[1] which at the present time is the largest in Europe: height above bottom of foundation, 375 feet; radius, 295 feet; length, 850 feet; amount of concrete, 12,000,000 cubic feet.

The water accumulated in the Grimsel

[1] The height of the Hoover Dam, in the Colorado River, is more than twice as great; its capacity is nearly 300 times that of the Spitallamm Dam.

THE INNERTKIRCHEN TRANSFORMER STATION

Lake is conducted through a horizontal tunnel to the Gelmer Lake and from there by means of a steel tube pressure line, eight feet in diameter and 3,700 feet long, to the Handeck Generating Station. The tube covers a difference of altitude of 1,750 feet with a maximum inclination of 72 per cent.

The problem of delivering the power from the Handeck Station to the load center presented serious difficulties. On account of the large number of avalanches coming down in the neighborhood of the generating station every winter, it was not considered safe to use high tension overhead lines, but it was finally decided that a reliable supply could be obtained by means of underground cables. Thus a special cable tunnel over three miles in length has been built to connect the generating station with the village of Guttannen. The power is stepped up at the generating station from 11,000 volts to 50,000 volts and is transmitted through cable circuits to Guttannen and from there by overhead lines to the Innertkirchen Transformer Station. The cable tunnel has been built large enough to permit the circulation of a small electric car which is the only means of communication during the winter season between the generating station and the villages in the lower part of the valley.

As a future extension of this development it is planned to collect the water at the turbine outlets of the generating station and to conduct it by means of a system of tunnels and pipe lines to another generating station which will be built near the present transformer station. The additional water would more than double the capacity of the hydroelectric plant.

## THE USE OF THE DIVING HELMET IN BIOLOGICAL STUDY[1]

THE use of the diving helmet in biological study was first introduced by the late Dr. Alfred G. Mayor, at the Tortugas Laboratory of the Carnegie Institution of Washington. Dr. Mayor and his associates used the diving helmet extensively, not only at Tortugas, but also around islands of the South Pacific. Dr. William Beebe has also employed the helmet for his studies of the submarine fauna in Haiti and Bermuda.

The form of helmet which these zoologists used was one which had been devised for work around yachts where it was necessary to go down under the boat to make examinations and repairs. It is so simple a device that it seems surprising that it has not come into more general use. It consists essentially of a brass hood with a glass front which fits over the head and rests on the shoulders of the diver and is held down by lead weights which are attached on the front and back sides. From this hood an ordinary garden hose runs to an air pump located in the boat. The person who is about to go down to examine objects under the water stands on a ladder which is let down from the side of the boat, and others in the boat place the helmet over his head as shown in Figs. 1 and 2. He then descends the ladder to the bottom as the man at the pump forces air down into the hood, the excess bubbling up around the shoulders and chest. With a long hose the diver can wander around for considerable distances. His hands are free and he can carry a basket or bucket with him and place specimens in this, or he can sit down under water and make sketches or notes on a zinc pad as Dr. Beebe is shown doing in Fig. 3. He can also take down a specially devised moving picture camera which is enclosed in a water-tight brass box, as shown in Fig. 4, and can thus make motion pictures of fishes and other objects at any depth to which sufficient light penetrates. In tropical waters it is pos-

[1] Photos by Dr. William Beebe.

FIG. 1. PLACING DIVING HELMET OVER THE HEAD OF A PERSON ABOUT TO DESCEND.

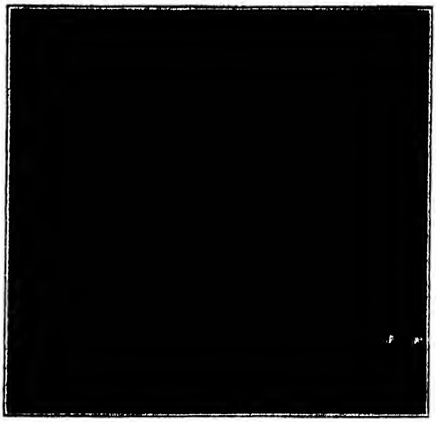


FIG. 3. DR. BEEBE SITTING UNDER WATER ON A CORAL REEF AND MAKING SKETCHES AND NOTES.

sible to take good photographs at a depth as great as fifty feet or more; but in general the diving helmet is used in water not more than thirty feet in depth, owing to the discomfort which comes from the pressure of the water on the chest of the diver, or the pressure of the air within the diving helmet. Under water photographs at a depth of twenty to thirty feet in clear waters of Bermuda are perfectly feasible, as is shown in Figs. 5 and 6.

The type of diving helmet shown in Figs. 1 and 2 is somewhat more complex and expensive than is absolutely necessary. Helmets have been made for the Bermuda Biological Station by an ordinary coppersmith, which are just as useful and much less expensive than the type shown. Indeed some boys in Bermuda have used an ordinary wooden box with a glass front, which is notched at the ends to fit over the shoulders and from which a garden hose runs up to a cheap air pump. Such a box must be heavily weighted to hold it down on the shoulders when one is submerged, but it serves the purpose of submarine observa-

FIG. 2. DIVING HELMET IN POSITION OVER THE HEAD OF THE DIVER.

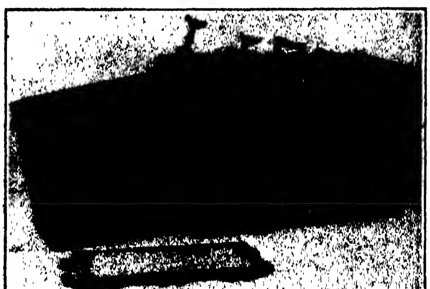


FIG. 4. CAMERA AND BRASS BOX USED BY DR. BEEBE FOR UNDER WATER MOVIES.

Fig. 5. Under water photograph of brain coral, sea fans and reef fish.

Fig. 6. Under water photograph of reef fish, tube worm and living coral.

tion almost as well as an expensive brass helmet. A good air pump is the usual two-cylinder beer pump, but almost any force pump will serve.

Such a helmet is of decided value in examining submarine objects which stand at a little distance above the bottom. It is one of the disadvantages of this helmet that one must keep it in a nearly vertical position, since otherwise air would escape and water would enter. One of the peculiar beauties of this instrument, however, is that if any accident happens it can be thrown off readily and the diver can come up as he would if he had dived without any helmet.

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## EPIDEMIC ENCEPHALITIS

The word "encephalitis," from its etymology, means simply inflammation of the brain, and can be used to designate many different varieties of this condition. About the end of the world war there was recognized a form of encephalitis occurring in groups of cases and usually characterized by apparent drowsiness or lethargy. This form was therefore called "lethargic encephalitis" or, in popular parlance, "sleeping sickness." The latter term, however, already had another meaning; it was the name given to an entirely different condition, a disease confined to tropical Africa, caused by a microscopic one-celled organism (trypanosome), and conveyed by the tsetse fly. The tendency now is to abandon the term "lethargic encephalitis" in favor of the "epidemic encephalitis," because a considerable number of the cases show excitement and increased activity rather than lethargy, and because the grouping of the cases is often such as practically to constitute an epidemic.

In many places and at most times, nevertheless, the disease has occurred diffusely, without special tendency toward any particular grouping or epidemic prevalence, and even in epidemics the cases have been, as a rule, without obvious relation to each other. This has been particularly true in the United States, the largest aggregations of cases at any one time being where one would expect them—in the largest city, New York. Here they amounted to over 500 during the months of February and March, 1923, but at every season and in

every place the toll of cases went on, causing more deaths in most years than poliomyelitis (infantile paralysis). The proportion of those afflicted who died is difficult to discover; for in a disease occurring in such a scattered fashion the numbers of those stricken are not so well reported as are the deaths, but probably the death rate among those who contracted the disease would amount to 20 per cent. or more. Striking nervous and mental troubles followed in some of the cases, so that the disease came to be one of the most dreaded of acute infections.

From July 31, up to September 14, 1933, there were reported in the metropolitan area of St. Louis 800 cases of epidemic encephalitis with 144 deaths, an indicated case fatality rate of 18 per cent. Cases of apparently the same inception have been reported from other cities in Missouri and neighboring states, but it is to be noted that so-called epidemic, or lethargic encephalitis, and encephalitis not otherwise designated have a yearly incidence throughout the entire United States similar in magnitude to poliomyelitis as judged from mortality statistics, usually without the marked seasonal and yearly fluctuation of poliomyelitis.

Cases of lethargic encephalitis occur yearly in St. Louis, the heaviest preceding incidence having been in 1919, 1924 and 1932. Relatively fewer epidemics of this disease have been reported in the United States than in other parts of the world, the disease in the United States being apparently sporadic or endemic. Such outbreaks as have occurred in this country have previously been, as is usual elsewhere, in winter or early spring.

The clinical picture of the St. Louis outbreak is that of a general febrile disturbance, often with gastro-intestinal symptoms such as vomiting, constipation or diarrhea; evidences of cerebral involvement—an apathetic or immobile facial expression, usually somnolence, stupor, coma or delirium; usually a moderately stiff neck, with headache, which is often the first and most pronounced symptom, and other pains, as of the abdomen or legs; tremor and catatonic semi-rigidity are common in the more severe cases. Tendon reflexes, such as those of the elbow, knee, ankle and superficial reflexes tend to be irregularly diminished or absent, and to vary from day to day. Some patients are very restless and have to be restrained. Irregular paralysis may occur. Many cases are less typical, but in this outbreak the doubtful cases have usually been found to be positive by spinal puncture and further course or by necropsy. The triad of symptoms is a febrile course, evidence of cerebral involvement and mild meningeal signs. The duration of the fever stage is irregular—the temperature may be normal in a few days. Probabilities as to sequelae can not be stated at present. The milder cases which have recovered so far are apparently restored to good health.

Pathologically the lesions are of the same nature but are at a higher level and more diffused than in the usual cases of lethargic encephalitis, the cortex is involved and there is no tendency toward special localization in the central system, such as the basal ganglia and the brain stem.

The outbreak which most closely approaches this is that which occurred on the western side of the Inland Sea in Japan in 1924, and described by Kanoko and Aoki in 1928 in *Ergebnisse der inneren Medizin und Kinderheilkunde*, Vol. 34, p. 342.

The incubation period is uncertain. There are indications that it may be five to twelve days. The onset is usually fairly sudden, that is, covering not more than one to three days.

Dr. Margaret Smith, a pathologist working with the St. Louis Committee, announced to the St. Louis Medical Society on September 1 that she had found, in over half the specimens examined, a microscopic formation known as "inclusion bodies," in kidney cells.

Such a formation is common in diseases caused by germs small enough to pass through porcelain filters, and therefore called filterable viruses, and this particular finding may help to identify fatal cases of the disease outside the present epidemic focus.

A report on September 8, to the Metropolitan Health Council of St. Louis, of an attempt to transmit encephalitis to monkeys, by R. S. Muckenfuss, assistant professor of medicine, Washington University, and Charles Armstrong, Surgeon, U. S. Public Health Service, and H. A. McCordock, associate professor of pathology, Washington University, states that since the beginning of the outbreak of encephalitis in St. Louis numerous animals of different species have been inoculated with materials of several kinds from patients suffering from the disease. Most of these animals have shown no signs of illness. Six monkeys inoculated with material from five different patients dying of encephalitis have shown fever beginning from the eighth to the fourteenth day after inoculation. Coincident with the rise of temperature tremors, incoordination and weakness have appeared. Three of these animals have been submitted to pathological examination and the central nervous system showed lesions consistent with the pictures found in human epidemic encephalitis.

Inoculation of material from these monkeys into numerous monkeys is also progressing.

While these results are encouraging many weeks' work has yet to be done before it can be stated that the human disease has been established in animals.

It has been found that neither water nor milk is a major factor in the spread of this epidemic, and at present the evidence points to a manner of spread similar to that of poliomyelitis. The precautions to be taken are, therefore, similar to those which would be used in an outbreak of infantile paralysis of like intensity. In the case of such a summer disease, occurring predominantly in suburban sections, the possibility of insect transmission can not be eliminated without intensive and prolonged study. Screening of patients is therefore advised, and measures directed toward the reduction of insects, particularly mosquitoes, are reasonable. There is no evidence, however, which would justify the expenditure, for the prevention of this disease, of the large sums necessary to do really effective mosquito elimination in the area in question.

Precautions have included the isolation of the patient for three weeks. The furnishing by the St. Louis authorities of almost complete hospitalization has also probably aided in more prompt and complete recovery.

The possibility that this new type of epidemic encephalitis may in future years show a more intense prevalence renders urgent as complete a study of this epidemic as possible. Fortunately the mobilization of expert personnel and particularly the remarkable mutual cooperation of the St. Louis and Washington Universities, the medical profession, the hospitals and the health authorities are most favorable to such a study.

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# ON THE NATURE AND THE LIMITATIONS OF COSMICAL INQUIRIES

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EARLY cosmogonies were almost entirely fanciful in character and were often largely of emotional or religious import. Only within the last few hundred years have we been able to produce cosmogonies with truly scientific pretentions. In the last two decades activity has increased markedly, beginning perhaps with the generalized theory of relativity of Einstein, followed by the work of Eddington, Jeans and Milne on the structure of the stars, and more recently by the theory of the expanding universe of le Maitre and the speculations of Tolman on cosmical thermodynamics. As in physics, probably the chief stimulus to recent activity is to be sought in our rapidly expanding experimental knowledge. It is obvious, however, that there are certain permanent limitations on the possible observational material provided by astronomy; we shall never be able to get into the inside of the stars, for example, or to go back a million years in time. Corresponding to these observational characteristics, there must therefore be certain essential differences between the nature of the structure that we can erect on these observations and other observational disciplines, such as physics, where the observational control is much more far reaching and intimate. In the following I shall attempt to give some analysis of the nature of the structure that can be erected on the observational material of astronomy. I shall seek to find the nature of the structure in terms of "operations"; our study will involve an examination of the nature of the observational material, of the methods used in interpreting this material, and of the methods by which we may check the validity of any solutions that we may find.

The observational material is subject to one obvious and essential limitation in that it is almost entirely optical in character. The only exception consists in the examination of actual celestial material which reaches the surface of the earth in the form of meteorites. Knowledge of this sort is at present very scanty, although it is daily becoming more important; it will always, however, be subject to obvious vital limitations due to the small size of any such meteoric material with which we can deal. The optical material consists, in the first place, of observations of the direction of the heavenly bodies; secondly, of the intensity of the total radiation from each individual object; thirdly, of the spectral characteristics of this radiation; and finally, in a few cases, of interference or other phenomena involving differences in the character of the radiation from different parts of the same object.

Measurements of direction are of high

precision, down to a small fraction of a second of arc. This is sufficient, by the method of parallax, to give fairly good information about the distances of the nearer objects. No measurement of astronomical distance, however, has an accuracy of much more than 0.1 per cent. Beyond the range of parallax, observation gives merely a projection in two dimensions of position, and distance has to be estimated by indirect methods involving extrapolations of observations made in the parallax zone, where it is possible to test the legitimacy of the method. Perhaps the most important of these methods is the estimate of the distance of the Cepheid variables in terms of an empirical connection between the size and the period established in the zone of parallax. This method is used by very wide extrapolation. Any such extrapolation must be prepared to defend itself against the criticism that there may be systematic changes at great distances in the connection between period and size. Such a defense is impossible until we have more exact knowledge than at present of the mechanism responsible for the variation of the Cepheids, and in any event a defense would always be impossible against the suggestion of the existence of effects at present unknown. We have to make our extrapolation as we do because in our ignorance we are powerless to suggest any plausible way in which the observed connection between size and period might be different.

The astronomer is forced to go even further than this, however. Much observation has developed in him certain "hunches." For instance, if he sees projected on the celestial sphere a large number of stars, far beyond the parallax distance, all grouped within a small disk, such as would be the case if he were observing a globular cluster, he will reverse the argument and say that the observed stars are actually grouped together in space into a globular cluster. Further, if he is fortunate enough to find within the group Cepheid variables, he will fix the distance of the whole group by the extrapolated distance of these variables. If the distances of all the Cepheids turn out to be nearly the same, the assumption of an actual globular cluster is felt to have a high degree of "probability."

By hook or by crook, therefore, the astronomer is able to assign distances to a large part of his observed objects; the confidence which he feels in these distances decreases as the absolute value of the distance increases.

The distribution of light in the spectrum of each star gives information about the mean temperature of the effective radiating surface and the chemical composition of this surface. Inference as to these quantities is made in large part on the basis of laboratory measurements, but also, especially as to the effective temperatures, on the basis of theory by which the effects of temperature and pressure on the dissociation of the elements may be extrapolated to temperatures and pressures beyond experimental reach. The theory involves quantum mechanics and thermodynamics, and we are fairly well satisfied with it, for the extrapolations are not particularly large as such things go. The inferences about the chemical composition are also satisfactory; in fact I think any astronomer or physicist would regard this as perhaps the most satisfactory part of our information. But even here, the assumption has to be made that the laws which we find in our laboratory experiments are not essentially modified under the extremely different stellar conditions, and I suppose it would be impossible to give a thoroughly logical answer to a carping critic who wanted to insist that this is really only an assumption and might not be legitimate. The carping critic will, however, find it impossible to convince a physicist that 5,000 spectrum

lines, all in approximately the same position, do not mean the same element, iron, in the star that they do on the earth. The argument again here rests on considerations of probability, which appeal to every one with scientific experience, but which nevertheless involve vague and imperfectly understood ideas which have so far eluded precise formulation.

The optical data sometimes permit estimates of the angular diameter of the star by interference methods, but the estimate of size is usually more indirect, involving the assumption of the universality of various empirical relations which are capable of direct verification in only a few favorable cases. At any rate, whatever the details of the method, the astronomer has estimates of the size of a large number of the stars, of precision much less than the precision of the best distances.

The mass of a star may be determined if we are fortunate enough to be dealing with a star which constitutes one member of a binary, the period and the separation of which may be observed. The mass of a large number of stars has been determined in this way. In calculating the mass from these data, the inverse square law of gravitation has to be assumed, with the same constants as observed in the solar system, and again there is no defense against the criticism of possible changes in the law of gravitation at great distances or in remote epochs of time.

Finally, observations of position at different times are accurate enough to give the apparent motions of a number of celestial objects; these combined with distance give the velocity in space perpendicular to the line of sight. Spectroscopic observations of the Doppler effect give the radial components of velocity, assuming that we know how to separate the Doppler effect from other effects giving rise to spectral shifts. Altogether, there is a rather large amount of material permitting us to give motions in space of varying degrees of accuracy.

Besides the characteristics of the data of astronomy already discussed, there is one other very essential characteristic, in that it is all "observational" in the narrower sense. We have to take what we find, without the possibility of studying what happens when we vary the conditions, which constitute such a powerful method in physics and chemistry. Astronomy is the observational science *par excellence;* geology is much like it but with growing possibilities of experimental control afforded by geophysics, and perhaps we may next place biology, until recently an observational science, but becoming rapidly completely experimental.

Such is the nature of the observational material and the inferences it allows as to distances, sizes, motions, compositions and physical state. Our problem is now to organize this material and bring it into coordination with other branches of knowledge in such a way that we feel that we understand the resulting structure. This we may perhaps define as the problem of cosmogony in the broadest sense. In the working out of the problem we may perhaps recognize two main aspects. There is in the first place the problem of inferring from our observational material what the present complete structure of the universe is; this involves, for example, determining the nature of the inside of a star, and in general inferring the unobservable parts from what we observe. Then in the second place there is the problem of extrapolating our observations backward and forward in time in order that we may get some idea of where our universe came from and what is its future. This latter is by many regarded as the most interesting task of cosmogony. This extrapolation forward and backward should, if the present configuration is completely known, be capable of unique

performance, so that we should be able to obtain a unique answer to our questions about past and future. But in view of the extreme incompleteness of our understanding of the present configuration, this ideal is very far from attainment. In fact, instead of making a straightforward extrapolation from the present configuration, the process is often reversed and inferential information about the present configuration obtained on the basis of what would be involved in the way of extrapolation. There are, in the first place, the data of geology controlling any extrapolation; it is obvious that our backward extrapolations must provide a long enough past for the demands of the geologist, and any limitations which requirements of this nature impose may be accepted as perfectly legitimate. We may be grudging in our acceptance of this control, however, because we recognize that we ought to be able to reproduce the past of geology without aid from this adventitious course. Aside from this perfectly legitimate demand which we make on our extrapolation, we make other demands which we would find it harder to justify on any scientific ground. For example, we probably shall eventually reject any reconstruction of the past as highly "improbable" which represents all the matter of the universe as having originally constituted a single giant atom, in spite of le Maitre, and I am perfectly sure that any extrapolation into the future which predicted the destruction of the entire cosmos within 1,000 years would be at once rejected, although perhaps unconsciously, as being derogatory to human dignity.

In general the problem of cosmogony is so difficult that no sort of control or argument appears to be neglected that can have any bearing on the problem, even if the argument is as purely emotional as that just suggested.

We are now ready to consider the details of the attack on the problem of cosmogony, and it is natural to first set ourselves the problem of understanding how the individual units, the stars, are constructed. What we have given is the surface temperature, chemical composition, total size and total mass, and we are required to reconstruct the state of affairs at every interior point. At any interior point we must know the temperature, composition and pressure, and we must know how these quantities vary from point to point. The point to point variation is controlled by the differential equations of mechanics and thermodynamics, into which enter the parameters which determine the pertinent physical properties of the stellar matter, such as emissivity, absorption, etc. We assume that our knowledge of the nature of the material is sufficient to determine these parameters when temperature, composition and pressure are given, but it is only recently that enough data have been accumulated in the physical laboratory to give us the slightest confidence in our assumptions about these quantities. The problem in general features is not unlike other problems to which physics can give an exact solution, such, for example, as the problem of elasticity. In elasticity theory we are given a body of known physical properties subject to a given set of forces acting over its external surface, and perhaps other forces like those of gravitation acting on the material inside, and we are required to find the stress and strain at every interior point. It is possible to give a mathematical proof that a unique solution exists. Our physical intuition leads us to expect similarly a unique solution for a star, but it is still far from evident what the exact mathematical conditions are which would lead to such a unique solution. In fact the general problem of finding the appropriate mathematical method by which to attack this problem would seem not yet to be definitely settled.

Certain plausible mathematical formulations have been rejected simply on the basis that in the solution they lead to infinities at the center. Now an infinity in a solution is no reason for rejecting an equation which leads to it. The validity of the equation is a matter which permits of direct test, and if under some conditions infinite solutions are demanded, the conclusion is that the physical assumptions which were at the basis of the equations have ceased to be valid, and must be replaced by others, the original equation still retaining its validity over the range within which it was established. The procedure by which the straightforward solution of the equation which naturally presents itself has been replaced is a complicated one of trial and error, starting with assumed conditions at the center and working out until we find conditions at the exterior as nearly as possible like those observed. Success has not been impressive and it is not certain that a single type of equation is adequate for the solution.

The mathematical difficulties in the way of the construction of a model of a star are therefore severe enough; the physical difficulties are not less formidable. The mathematical solutions, which have been obtained thus far, agree in assigning to the interior of the star perfectly scandalous temperatures and pressures—temperatures of the order of tens of millions of degrees, and pressures of the order of tens of millions of atmospheres. Such conditions are so tremendously beyond the range of anything that can be obtained in the laboratory that any extrapolation of properties observed in the laboratory must be viewed with extreme suspicion, even when this extrapolation is made with the help of the best theories that we have at present. Entirely unknown sorts of behavior of matter under these extreme conditions are to be expected. The recently discovered dense stars show definitely enough the possibility of matter existing in hitherto unknown dense forms, and it is not yet agreed whether we are to expect a core of such dense matter at the center of each star or not. The recent discoveries of the neutron and positive electron also tremendously affect the possibilities and there is the possibility of elements of very high atomic weights, not hitherto known. Ignoring these difficulties, however, models of a sort have been constructed which have been successful in reproducing some of the outstanding observational regularities of the stars, such as the relation discovered by Eddington between mass and total brightness.

In spite of all the vagueness of our present formulations and our ignorance of the physical conditions inside the star, which we might be inclined to think would leave open sufficient possibilities to permit an eventual exact solution, every stellar model at once encounters one difficulty which peremptorily forces us to abandon our original program of completely reconstructing the star in terms of data of the laboratory. The difficulty, of course, is concerned with the radiation. The rate at which a star is losing energy by radiation is capable of measurement. (This involves the assumption that the radiation in every direction is the same as in the direction of the earth. Attempts have been made to postulate that radiation takes place only in the direction of bodies in position to receive the radiation, but this possible way out has encountered insuperable difficulties, such as that of accounting for the radiational equilibrium of the earth.) The total amount of energy radiated in geological time can therefore be calculated, and this turns out to be much greater than accounted for by any known source of radiational energy. It is not necessary here to assume a complete law of conservation of energy—the energy concept

encounters logical and formal difficulties when we attempt to apply it to systems in which only uni-directional processes are taking place. All that is necessary is the observational fact that there is no known source of radiation which does not involve the exhaustion of its source; energy is radiated only at the expense of some sort of permanent change in its source. It is perhaps worth mentioning in passing that the times involved are so long that the direct observation of the cooling or other exhaustion of any celestial body in consequence of its radiation is hopelessly beyond us. Granting, however, that radiation means exhaustion celestially as well as terrestrially, an exploration of all known sources of energy discloses that they are inadequate. It seems unavoidable therefore to assume some unknown source. It happens that our present experience contains the suggestion of one possibility which, although not actually realized, does not demand a very revolting extrapolation of laboratory conditions. This is the transformation of matter into energy, first suggested by Einstein's relativity theory, in which it appeared that radiation of energy was accompanied by loss of mass of amount $m = E/c^2$. This equivalence of mass and energy has been established with high probability for the radioactive transformations. The largest effect of this kind to be expected cosmically is the change of mass accompanying the transformation of four hydrogens into one helium. This transformation perhaps provides an adequate source of energy, but the margin of safety is not large, and a number of cosmologists do not feel that this is the solution. They prefer to go further and find the source of energy in the complete annihilation of matter when electron combines with proton. This very probably provides an adequate source. But on the other hand, the process has never been observed and is purely inferential; the great argument is that it fits neatly into our mathematical formulation of relativity theory.

In any event the important feature for us is that we have unequivocally encountered a situation which shows that our original program is not capable of execution, but we must assume processes not directly given to us by laboratory experience. Having thus once let down the bars, a flood of possibilities descends upon us, and the question is, where are we going to stop? There are many other places where it would be plausible to look for unknown processes. What is the basis for assuming that the conservation of energy is sacrosanct? Why may we not simply postulate that energy is created in a star? Inside a star radiation is continually being emitted, traveling a short distance and then being reabsorbed. Suppose that conservation fails by a small percentage amount at each process. One can get some idea of the relative number of total emission processes going on in the star compared with the number which are concerned in the net radiated energy by considering that in the sun the ordinary thermal content would supply the radiational energy for 15,000,000 years, and that a beam of light travels the solar radius in something of the order of 2 seconds. If conservation at each elementary quantum act of emission and reabsorption fails by an amount fantastically beyond the possibility of direct experimental verification, the total net radiation is adequately accounted for. Or again, how accurately is the inverse square law of gravitation checked by any direct observation under conditions approximating those in the interior of a star? What basis have we for thinking that gravitational screening may not be a property of matter with density 50,000 times that of water, when claims have been made that the effect has been detected under terrestrial conditions? What is the basis for thinking that the

ordinary laws of electrodynamics retain their simple linear form when electron and proton are as close together as they must be or when we have as intense radiational fields as in the stars. Physicists are already openly discussing the necessity of modifying the accepted quantum laws for the nucleus. Why may not matter even be created inside the stars? The universe had to come from somewhere.

When one considers the criteria by which he attempts to judge the seriousness of these various possibilities I believe that it must be conceded that the whole matter is rather vague. Probably the broadest characterization of the criterion which we more or less unconsciously apply is that of simplicity, the same criterion which we use in other speculative work when the problem is undetermined. But simplicity has no absolute meaning; what may be simple from the point of view of a mathematical equation may be more complicated when the procedure is formulated in words or translated into physical operations. An example is the procedure for measuring the length of a moving object in relativity theory; the actual definition corresponds to simple equations, but is much more complicated when expressed in words than the naïve and rejected procedure of measuring the moving object by the application of meter sticks moving with the same velocity. By what right does the mathematical formulation acquire precedence? In this example the situation is completely determined and a decision may be made, but no such decision is possible in cosmogony.

In describing ordinary physical experience rough criteria of simplicity have stood the check of workability because it has been found possible to reproduce our physical experience in simple terms. Without such an experimental proof of the possibility of simplicity it would seem that there can be no logical reason for expecting simplicity in preference to complication. Now in the cosmic case the check against experience, in order to choose between rival theories, is not possible, each theory being constructed so as to be equally capable of dealing with the facts, and the criterion of simplicity loses objective probability. But other physical experience would suggest that in this realm of totally unknown conditions, pressures of $10^7$ atmospheres and densities of 50,000, nature would be expected to become more complicated, and simplicity would be expected to fail. We might argue, therefore, that the more complicated of two rival theories would have the greater chance of being correct. But in the absence of specific indications of the direction which the complication should take, we must show no preference for one complicating hypothesis as distinguished from another, so that an attitude of perfect neutrality demands that we reject every complicating hypothesis that we can and thus revert to simplicity. In this domain, therefore, our expectation of simplicity in the physical phenomena fails us, whereas simplicity in our theories remains because it expresses most perfectly our complete ignorance.

It may happen that different models are equally capable of reproducing the present observational properties of the stars, but when extrapolated in time different pasts or futures may be demanded. Granted that the single condition is satisfied that a star like the sun has a tolerably constant past as far back as geological time, what further criterion in addition to those already discussed shall be applied in making our selection? One criterion of intrinsic probability is very definitely applied in practise, namely if any solution shows scattered throughout the universe stars in different stages of evolution, satisfaction is felt. Thus if my solution for a

present red giant indicates a condition at some future time such as I now find in some white star, I am pleased, and feel that my solution has a better chance of being correct. That is, it seems probable to me that the stellar universe as at present observed contains stars in different stages of evolution. This involves the thesis that the stars did not all come into being at the same time, but successively. Why does this seem more plausible than the assumption that they all started together? I think examination will show that there is nothing very rigorous here, and that the argument is to some extent a "hunch" argument, resting partly on the feeling that in the nebulae we are observing localities in which stars are actually being born at the present time.

The problem of the structure of a star is the problem of the atom of astronomy. Besides this there is the problem of the aggregate of the stars, just as we have a kinetic theory of gases in addition to the problem of atomic structure. In kinetic theory the precise structure of the atom makes little difference as long as the atom has certain very general properties of elasticity, etc. In the cosmic case there is a closer connection between the problem of the structure of the unit and of the ensemble, for the life of the ensemble extrapolated backward must not be shorter than the life of the individual units. There is obviously no such corresponding condition in kinetic theory. For the present, however, we neglect this aspect of the problem, and confine our attention to the problem of finding the positions of the stars in past and future time, treating the stars as unalterable units.

The first impression on approaching this problem is, of course, one of overwhelming complexity; mathematics has not been able to completely solve the problem of even three bodies moving under their mutual gravitation. Some sort of simplification is obviously necessary and we must be satisfied with only a rough answer to our problem. The first question is: what data are necessary in order to ensure a determinate answer? If the problem were one of ordinary mechanics, in which the mutual forces between the stars were known as soon as their mutual distances were known, it would be sufficient to give the present positions and velocities of all the stars. This we may hope to approximate observationally, although the velocities are determinable only very roughly. But the stellar problem is not a problem of ordinary mechanics, because the distances of separation of the stars are so great that the time of propagation of gravitation is important. The analogue of this problem is the retarded potential problem of electrodynamics. Here the solution is not determinate unless the initial positions and velocities of all the particles is given, and in addition the initial values of the electric and magnetic fields at every point of space. The analogue for the cosmic problem of this last requirement is a knowledge of the present gravitational field at every point of space. But the gravitational field throughout space is not observable, so that in principle the problem of extrapolating backward or forward in time is indeterminate, and the most that we can hope for, even with infinite mathematical skill, would be an approximate solution in which there is an indetermination which would be expected to grow in importance as the interval of time becomes longer. I do not know whether a quantitative discussion has been made of the importance of this neglected factor or not.

There are other mathematical difficulties in the case of even so comparatively simple a system as the solar system. Brown is authority for the statement that we can not be sure of gravitational stability for more than $10^8$ years. This

is much less than geological time, so that apparently the mathematical extrapolation runs into difficulties in times that are shorter than we know are necessary. One can never hope, therefore, to get a rigorous solution back to the time required. Another difficulty has been pointed out by Brown, who thinks that the equations of gravitational motion of so complicated a system may have such a high number of singularities that it is observationally impossible to supply the number of positions and velocities necessary to determine a solution.

There is another difficulty of a fundamental sort. The Heisenberg principle of indetermination does not permit of the simultaneous observations of position and velocity which are necessary for extrapolation, but there is a necessary reciprocal error in the observation of these two quantities, which means an error growing with time in any possible extrapolation. Over longer and longer intervals of time the details become more blurred, until the actual identity of the objects that we are talking about is lost, and we could not tell, for example, whether a star which we extrapolated to be in a certain position in $10^{50}$ years was Capella or Vega. Prediction does no good if we have no way of telling what object it is that we are talking about, so that we may say that it is meaningless to attempt to extrapolate time so far forward or backward. Or in other words, the concept of time itself fails if the extrapolation is too extensive. This of course all assumes the validity of the Heisenberg principle when applied to the motion of the stars. It is perhaps needless to say that there is not a scrap of experimental evidence for this, so that our application of the principle is nothing but an enormous extrapolation of a mathematically simple law, made in the same spirit as our assumption of a mathematically exact inverse square law or exact conservation of energy for individual quantum processes.

In spite of all these unavoidable vaguenesses in the extrapolations of positional astronomy, there are certain facts of observation which can not hide behind the possibilities left open in this way, but they indicate the need of some drastic rearrangements in our ordinary explanations, just as the radiational difficulty with the single star demanded the discovery of some new source of energy. The most striking of such phenomena is perhaps the shift in the relative angular position of the stars when their light passes close to the edge of the sun. The only solution proposed which has been at all well received is that of Einstein in his generalized theory of relativity. This has demanded a radical reconstruction of the four dimensional union of space and time with which special relativity theory was satisfied, and involves the idea of a curvature of space-time in the gravitational field. There is confirmatory evidence of this solution in the shift in the perihelion of Mercury and the displacement toward the red of lines radiated in an intense gravitational field, but these checks are not so striking as the other. In any event the entire scheme of explanation suffers from the logical difficulty that it is impossible to prove a curvature of space-time, which requires an infinite number of parameters for adequate specification, in terms of only three observational quantities. The fundamental assumption that space-time is curved can not be directly tested; for one thing, the space of astronomy is only optical, and the equivalence of optical and tactual space can never be adequately checked. The uniqueness of Einstein's solution can never be established; the argument for it, as in so many other cases, can only be the argument from simplicity in the mathematical formulation.

The differential equations of general relativity theory are not sufficient to completely solve the problem of the entire cosmos, but integration constants

appear for which we can offer no physical explanation, but which have to be accepted merely as brute facts. It is well known that entirely different behaviors are indicated in the stellar system at great distances accordingly as a positive or negative value is assumed for one of these constants, and that the observational material is not adequate to allow a choice. The expanding universe of le Maitre results from a particular choice of a constant of integration at a particular stage of the solution. It has been interesting in the last few years to follow the way in which opinions about the probable values of the constants have followed our increasing observational knowledge. We now have the experimental fact that the radiation emitted from the most distant objects is shifted toward the red by amounts indicating enormous velocities of recession if the ordinary Doppler explanation of the shift is accepted. But this property of radiation from distant objects can also be explained in terms of a proper space-time curvature, with the proper constant of integration. On what basis shall we choose one explanation in preference to the other? The preference at one time seemed to be in favor of a curvature, but at present it seems to be for a recession. The reversal of preference has been brought about by the discovery by le Maitre of a method of getting an expanding universe into a comparatively simple mathematical scheme. I believe that if a mathematician or astronomer were made to defend his present preference he could not do better than to urge that it seems *more probable* that the physical state of affairs should correspond to a mathematically simple scheme than to something more complex.

The same argument from feelings of probability occurs in many other places in astronomy. It is justifiable when one is engaged in statistical studies, comparing one collection of objects from one part of the sky with another from another. But in strict logic probability considerations apply only to large numbers or when it is possible to repeat the experimental conditions a great many times. The idea of probability never applies to individual physical situations; probability considerations can not apply to a single throw of dice, for example. The stellar universe is all there is, and it makes its history only once. Probability considerations do not properly apply to it at all. It would be most difficult to analyze just what is involved logically in the frequent application of this sort of an argument to the cosmos. I suspect that at bottom the argument would be found to revert to the old argument from simplicity, and to those hazy arguments, popularly phrased in the language of probability theory but logically quite different, by which we determine our course of conduct when we are confronted with situations about which we are largely ignorant.

We have thus been driven in our positional astronomy to postulate new effects, not directly verifiable by observation. But are there not other unobserved and new effects which we would expect on general grounds? Must we not assume that there are places where electrons and protons come into being? What about radiation? Does it come back? Does it recombine to give proton and electron? What is the significance of the cosmic rays? May not all our physical laws be undergoing a course of evolution, with slowly changing values of all constants?

The difficulties which we have thus far discussed are to a greater or less extent concerned with the details of working out various specific aspects of our problem, but there are more fundamental difficulties, already hinted at. One may well question whether the very concepts in terms of which we do our thinking are adequate to the situation. We have al-

ready met an example that suggests the sort of failure that we may find in our concepts. The energy concept of thermodynamics is rigorously defined in terms of processes which involve bringing the system back to its initial configuration; this is obviously impossible when the system is the entire cosmos, so that in the strict sense of thermodynamics one can not talk about a conservation of the "energy" of the universe. In this particular case we have seen that the formal failure of the energy concept is not of much importance, because for our purposes we can get along with only a partial aspect of the energy concept, and it is possible to find an ideal meaning for this partial concept in its application to the entire universe. But it is not so evident that we would be similarly successful in side-stepping the difficulties of other concepts. Practically every one of our physical concepts demands the performance of an experiment, which in the first place can be indefinitely repeated in time, and which in the second place involves dividing the universe into two parts, one isolated from the rest, on which experiments are made by an external agency, whose actions are supposed arbitrary and unaffected by what occurs inside the isolated region. This procedure evidently breaks down when the subject is the entire universe. How, for example, shall we define the mass of the entire universe to the satisfaction of a critic who insists that the mass of the whole is not the sum of the masses of the parts, a fact which we ourselves very well recognize even in small parts of the universe when we make our measurements accurate enough.

There are particular difficulties with the concept of time in addition to the possible difficulties connected with the Heisenberg principle, already mentioned. The crude difficulties of the naïve time concept have been long felt. Such a difficulty has already appeared in a loose phrase purposely introduced earlier in this paper when it was asked "May not matter even be created inside the stars? The universe had to come from somewhere." We are here face to face with the age-old dilemma; we demand an antecedent for everything of our experience and again an antecedent for the antecedent and so on in never ending regression, and on the other hand we demand equally insistently something in the beginning to start things off. The only answer is the brutal and unsatisfactory one that the urge of our minds to act in this way must be resisted because it does not work; the origin of the urge is in limited experience, and we must recognize that such experience may land us in inconsistencies when pushed too far. The only precise way of dealing with the concept of time is the operational one to which all modern physics seems to be driving us, and which I have expounded in other places. What do I mean from this point of view by the future? In the strictest sense what I at the present, as I sit in this chair, mean by the future is nothing but the complex of expectations which I can formulate to myself at the present, at which I arrive on the basis of all the regularities in nature which my past experience has disclosed to me. The operational meaning of the future, for me in the present, is the complex of those operations by which I deduce my expectations. But this severe meaning of the future will, I believe, be found to not quite correspond to what most people want to mean. We can go part way toward meeting this instinctive feeling by admitting another operation to our armory, the operation of waiting. The operational meaning of saying that I shall have lunch at 1 o'clock is that if I perform the operation of waiting until 1 o'clock I shall have certain experiences. There are many difficulties with this operation of "waiting" and I feel

that it is dangerous to admit it, but for the present purposes we may perhaps allow ourselves this liberality. The important immediate point for us is that none of us, I as I write, or you as you read, can possibly wait beyond the termination of our individual lives. Any possible meaning that the future can have for any individual must be sought in the things that can happen to him in his lifetime, or in an interval of not more than 200 years, a rather brief interval compared with astronomical times. Contemplation of this broadest possible meaning that we can give to the future will give, I believe, a rather different feeling about the significance of the predictions of astronomy. In physics the situation is qualitatively entirely different, for all the operations by which the fundamental concepts are defined and which are involved in the fundamental experiments are of such short duration that the "waiting" aspect hardly presents itself. However, the waiting aspect is always present to some extent, because operations are performed in time, and are composed of parts described in a prescribed order, so that on beginning a complicated operation one has to wait before one can perform the last part of it. Again, as so often before, we see that there are no hard and fast lines of demarcation between regions of validity of concepts.

With regard to past time, the operational meaning of the past is much more definite than that of the future, for there is no possibility of a questionable operation for the past corresponding to "waiting" for the future; I can never penetrate back into the past. The past for me, as I sit in my chair, means simply the aggregate of those reconstructions which I make on the basis of all the experience now at my command. It is evidently a most complicated thing, but is always subject to the limitations to which the reconstructions which I can make are subject. It means nothing to ask what was the past "actually," unaffected by the limitations of thought in reconstructing it. A proper realization of this again gives one a rather different feeling as to the significance of the extrapolations of cosmogony into the past.

Finally, I attempt to summarize the view to which this analysis leads us as to the nature of cosmogony. The essential limitations of the experimental material place cosmogony in a class by itself. It partakes as much as possible of the nature of the completely experimental subjects, physics and chemistry, but is compelled by necessity to introduce features relating to less sharply defined human activities verging into the artistic, the emotional and the metaphysical. The artistic instinct in the cosmologist finds expression in selecting those formulations or solutions, out of the many possible ones, which are most elegant or most simple. The emotional element is well illustrated by the attitude which various cosmologists take toward extrapolation into the indefinite past or future. There are diametrically opposite attitudes here. Thus to Tolman it is extremely repugnant to think of the universe being carried in time to such a configuration that extrapolation can be carried no further, which means either an act of creation at this epoch, or at least a fundamental change in the laws of nature. To Tolman the idea of a special situation presented by the problem of evolution which demands the assumption of new and unknown laws is so abhorrent as to make the whole picture almost unthinkable. This has driven him to hunt for oscillating solutions of the cosmic problem, which permit the universe to oscillate back and forth between extreme configurations, indefinitely repeated both in past and future, so that there is no limit in time either forward or backward. On the

other hand, to a man like Eddington, the idea of a universe continually oscillating between extremes is irreconcilable with feelings of a purpose in stellar evolution. Eddington exclaims that he is an "evolutionist, not a multiplicationist." He prefers a solution in which a definite act of creation has to be assumed in the past, or at least some sort of catastrophe initiating the present régime, and perhaps a gradual decline to the "heat death" of Boltzmann.

The metaphysical element I feel to be active in the attitude of many cosmologists to mathematics. By metaphysical I mean the assumption of the "existence" of validities for which there can be no operational control, a statement which in itself is almost meaningless from the operational point of view, and in fact I personally have no feeling for this sort of thing, and can only use the term "metaphysical" in describing behavior which I observe in other human animals. At any rate, I should call metaphysical the conviction that the universe is run on exact mathematical principles, and its corollary that it is possible for human beings by a fortunate *tour de force* to formulate these principles. I believe that this attitude is back of the sentiment of many cosmologists toward Einstein's differential equations of generalized relativity theory—when, for example, I ask an eminent cosmologist in conversation why he does not give up the Einstein equations if they make him so much trouble, and he replies that such a thing is unthinkable, that these are the only things that we are really sure of.

I believe that there are dangers in any subject in which there is such an unavoidable mixture of purely "scientific" and "human" elements. It seems to me that there is particular danger of introducing actual inconsistencies into the structure if the metaphysical attitude with regard to mathematics is so far adopted as to obscure the perfectly legitimate use of mathematics in attaining simplicity of formulation. The dangers, I hope, may be minimized by discussions like this. But even a perfectly clear-eyed consciousness of the nature of cosmogony will still leave it a subject in which are inextricably mingled together the austere aspects of a purely scientific subject with the warmer and incalculable aspects of a "humanity." To many persons this will constitute an abiding source of fascination; it has at least added to the pleasure of this attempt at analysis.[1]

[1] After sending the manuscript of this article to press, I have read the inaugural lecture of Professor H. H. Plaskett, at Oxford University on April 28, 1933, entitled "The Place of Observation in Astronomy." There are many similarities between his points of view and those above.

# CHARACTERISTIC FEATURES OF MATHEMATICS AND OF ITS HISTORY

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WHAT machines are to the industrial world mathematics is to the thought world. Just as a machine is useful only in the hands of an intelligent guide, so theoretical mathematics is really useful only when its postulates are understood and its conclusions are construed in harmony therewith. Both are employed largely because they economize effort. They are, however, used also because they enable the human race to accomplish what would otherwise be impossible. For instance, the rapid transportations of to-day would be impossible without machinery, and the measurement of distances to and between heavenly bodies would be impossible without mathematics. The modern industrial world finds machines indispensable and the modern intellectual world has enjoyed the fruits of mathematics too long and in too many ways to entertain seriously the idea of returning to a thought world devoid of mathematics, even if individuals frequently do this after their college days.

According to Pappus, the simple machine known as the lever impressed Archimedes so forcibly that he said, "Give me a place to stand on and I can move the earth." Similarly, the Pythagorean philosopher Philolaus is said to have remarked that "All things which can be known have number; for it is not possible that without number anything can either be conceived or known." The fundamental place of the lever in machinery corresponds to the fundamental position of the concept of number among the mathematical concepts, and the recognition of the importance of these concepts may have given rise to the outbursts of enthusiasm just noted. Primitive people sometimes combine even yet the name of a number so closely with the counted objects that they use different words for such numbers as 4 and 10 when they are applied to different objects.[1]

Such a waste of effort could not be tolerated indefinitely by the advancing sciences and the use of the same name for the number 4, for instance, independently not only of the objects counted but also of any concrete objects, exhibits a fundamental feature of the mathematical machines. The operation with abstract numbers is a man-made device to deal at a stroke with operations relating to an endless number of different objects. It would be difficult to find in the industrial world a more striking example of a machine which enables the individual to work with speed and great power. Abstraction in the intellectual world corresponds to power in the physical world, and mathematics is preeminently the science of the abstract which was inaugurated by the concept of abstract number in prehistoric times and has been greatly enhanced since then by the broadening of this concept and the introduction of others.

The use of unit fractions is one of the most striking examples in the history of mathematics of the suggestion of an elementary theorem for thousands of years before it was actually proved. In all the

[1] *Cf.* E. Fettweis, "Das Rechnen der Naturvölker," 1927, page 3.

cases which appear in the table at the opening of an ancient Egyptian work, all the denominators in the same problem differ from each other. It was, however, not explicitly proved in the literature before 1931 that a necessary and sufficient condition that a number is rational is that it is the sum of a finite number of distinct unit fractions and that these addenda can always be selected in an infinite number of different ways so as to be equal to any given rational number.[2] One of the characteristic features of the history of mathematics should be an emphasis on the suggested theorems and the misconceptions. From this point of view the theorem just noted is one of the most important relating to pre-Grecian mathematics and the view still held by L. Euler that every negative number is greater than infinity is one of the most important features of the history of negative numbers. Such features make the history of mathematics a study of thought development by the human race.

Calculating machines relate to only a small part of mathematics and effect a comparatively small saving of labor. The great saving is of a more theoretical character and underlies the creation of the abstract numbers which are utilized by the calculating machines. Hence our topic has only slight contact with these devices. While these machines began to be developed in the seventeenth century the abstractions upon which their usefulness largely depends were practically completed when our earliest extant mathematical records were made. The labor-saving feature of mathematics is more forcibly exhibited by the theory of permutation groups to which have been reduced not only various important questions relating to the theory of equations but also such a somewhat trivial question as the possible arrangements of the players at card tournaments when the number of players is of the form $2^m$ so that during $2^m - 1$ games each of the players shall have each of the others once as a partner and twice as an opponent.[3]

The history of group theory illustrates very clearly the fundamental principle of the history of mathematics that many simple theorems failed to command respectful attention until it became known that they are special cases of more general useful ones. These more general theorems were explicitly noted and led to explicit extensions not only upwards into their more complex ramifications but also downwards into their obvious details. Just as some people attain respectability only on account of their prominent close relatives, so some mathematical ideas have obtained positions among the more important results solely on account of their close connections. For instance, there is nothing more obvious than the groups of movements of some of the elementary geometric figures, such as the regular polygons. We now sometimes emphasize these groups even in elementary mathematics, as may be seen from the useful article on the elements of the theory of groups in the *Enciclopedia delle Matematiche Elementari*.[4]

It is difficult for me to believe that these groups were not observed by some of the ancients. It seems much more probable that they were actually observed by many of them but were regarded as too obvious and unimportant to deserve special mention. At least, no mention even of special cases thereof seems to appear in the mathematical literature before the latter half of the

[2] *American Mathematical Monthly*, vol. 38, p. 94.

[3] *Cf.* G. A. Miller, *Annals of Mathematics*, Vol. 19 (1917), p. 44.

[4] Vol. 1, part 2 (1932), p. 63.

eighteenth century. The rapid progress of mathematics during the nineteenth and the beginning of the twentieth century is largely due to explicit presentations of the obvious in view of the contacts with broad theories which were then rapidly developed. It has recently been discovered that even the ancient Babylonians solved certain quadratic equations by completing the square just as we do now, but no mention of the fact that by completing the square we can always formally solve such an equation has as yet been found in their literature. They did not emphasize such obvious facts since they appeared to them to be isolated.

A characteristic feature of mathematics, and perhaps of all the sciences, is that it has been developed largely as a result of a quest for the comparatively simple but comprehensive. Insurmountable difficulties presented themselves at many points. In number theory, for instance, there remains the question whether the sum of the $n$th powers of two rational numbers can be the $n$th power of such a number when $n > 2$, in group theory we have not yet been able to determine whether there is a simple group of odd composite order, in geometry there is the unsolved four color problem, etc. Many such problems might have blocked mathematical advance if the mathematicians had not turned their attention to the easier problems and developed general theories relating thereto which embrace many well-known special results. Abstract group theory, in particular, is such a theory based on such special observations as the following:

The mathematical world became acquainted early with combinations of two elements of a given set of elements such that the result thereof is an element of the same set. For instance, the sum and the product of two numbers are numbers, a geometric movement followed by a second such movement is equivalent to a single geometric movement, the sum of two vectors is a vector, etc. Such combinations are very common, but they are not universal. A pie is quite distinct from the ingredients which enter therein and group theory did not originate in a bakery, notwithstanding the usefulness of this institution. It had its origin in the sphere of human experience which led the Biblical sage to remark "There is nothing new under the sun," notwithstanding the many results commonly accepted as new theorems which appeared in its development.

It may be desirable to refer here to a very unsatisfactory situation in regard to the use of the technical term group in the modern mathematical literature. This may be illustrated by referring to an introductory observation relating to this subject which appears in the part of the recent Italian encyclopedia of elementary mathematics noted above. It is here stated (page 20) that the notion of group has been greatly extended during the last fifty years by including therein operations or transformations whose number may be finite or infinite, whenever the transformation resulting from any two of them, applied successively, is equivalent to a single one of them. The natural inference therefrom is that such vague general notions have been enriched during the last fifty years by the extensive developments of group theory, while, as a matter of fact, not a single theorem thereof applies to them in their complete generality. Hence the statement is apt to be misleading.

It would be better to say that the notion of group is restricted by postulates and hence it can never be extended. A modification of these postulates is, of course, always in order and this may be what S. Lie had in mind when he asserted in his "Theorie der Transforma-

tionsgruppen"[5] that there are groups which involve neither the identity nor the inverse of each of their elements. The confusion which exists to-day along this line is exhibited by the fact that one can now find good recent authority for saying that the natural numbers when combined by multiplication form a group as well as for saying that they do not have this property. Fortunately, many writers state their postulates explicitly and hence avoid all such misunderstanding. One of the most satisfactory systems of group postulates asserts explicitly that only two elements can be combined at a time and that when more than two elements are combined successively they obey the associative law. Moreover, when any two of the symbols of the equation $xy=z$ are replaced by the same element or by two distinct elements of a group the equation will determine uniquely a third element thereof.

It is a somewhat remarkable fact that this simple formulation of the postulates of a group, which applies to those of infinite as well as to those of finite order, has not been more generally adopted by modern writers on this subject since it is briefer than others which are more frequently used and is in line with the fundamental tendency in mathematics towards brevity and comprehensiveness of expression. The term group is appropriate for a comparatively new subject since it is the only technical mathematical term for a large field whose etymology has not been traced back more than 400 years. It seems to have had a common origin in central Europe with the word crop and to have been first used in English in connection with decorations. The nature of the subject would be more clearly exhibited by the term combination which was employed earlier (about 1770) by J. L. Lagrange for the same subject. Perhaps the gregarious nature of the human race led to the adoption of the former term, which was first used in this connection by E. Galois (1811–1832). In fact, in its non-technical sense the group may have exerted a more powerful influence on the development of the number concept than the series.

A conspicuous feature of modern mathematics is the tendency of giving credit for the various decided advances to those who are supposed to have first exhibited them. For instance, in the two parts of the Italian encyclopedia on elementary mathematics which have appeared recently there are author indexes but no subject indexes. The custom of giving such credit has not always been followed. For instance, not a single historical note appears in the famous "Elements" of Euclid and we have no evidence to support the view that even a single mathematical theorem known before the times of the ancient Greeks was then credited to its author. The ancient Greeks inaugurated the credit giving custom in mathematics but not all of them practised it as has been noted in regard to Euclid. It represents an effort to create a lasting memorial to those who have enriched our intellectual lives and it is to be hoped that it will tend to attract more workers into the intellectual fields, which seem to be able to use indefinitely the growing numbers of workers who are no longer needed to provide our physical wants, in view of the growing efficiency of machinery.

The libraries and the laboratories of the world are peace centers not only because they provide enlightenment but also because they provide fields for lasting achievements even for the most ambitious. An organization like the American Sigma Xi aims to attract young university people into this field by acquainting them with some of the work-

[5] Vol. 1 (1888), p. 163.

ers therein and exposing them to the contagion of the enthusiasm of these workers. While the mathematical investigators do not constitute the largest group of scientific workers, more than 3,000 contribute now annually about 5,000 memoirs of sufficient importance to be recorded in the *Jahrbuch über die Fortschritte der Mathematik*, which has recorded such annual advances for more than sixty years. The first volume of this publication recorded less than 500 names of contributors to the advancement of our subject so that the number of mathematical contributors to-day is about six times as large as it was sixty years ago. For America the ratio of this increase is much larger since only four or five American contributors are noted in this first volume, while now this number is several hundred annually. Asaph Hall and Simon Newcomb are the most favorably known Americans whose contributions are mentioned in the said first volume. They are now best known on account of their astronomical achievements.

Mathematics is largely a science of equivalent variants. From the earliest times geometry and analysis have largely supported each other and each has provided a field of interpretation for results obtained in the other. Equivalent rational numbers presented themselves early in an infinite number of forms as common fractions and the restriction of constructions by ruler and compasses in Euclid's "Elements" corresponds to the limitation of finding only the real roots of real quadratic equations in analysis. The conjugates of a group are equivalent variants of each other and similar figures are equivalent under a certain group of transformations. By the principle of duality (which was cleared up in the early part of the nineteenth century by the discussions by J. D. Gergonne, J. V. Poncelet, and J. Plücker) various geometric theorems of different aspects are deduced from each other, and our common space may be regarded either as a point space or as a space of sets of numbers.

Up to the times of the ancient Greeks mathematics was essentially a consideration of relations between rational numbers. The theorems of geometry which were then considered relate to areas and volumes, and hence they were of a numerical nature. The ancient Greeks added thereto the study of geometric properties which were not of a numerical nature, such as the drawing of tangents to curves, but mathematics was confined to the study of numerical relations and geometric figures up to the time when the properties of groups began to be studied in the latter part of the eighteenth century. Group theory is not confined to the study of numerical relations or geometric figures even if it is illustrated by both of these subjects and has greatly enriched them. Elements had been combined since the beginning of mathematics but a special study of the laws of these combinations, even under the very strong restrictions imposed by group theory, marks a new line of development in mathematics, the wisdom of which is substantiated by the rapid developments of this subject in recent years and the numerous applications of the results obtained therein.

The permutations which were studied before the development of group theory were of a numerical nature. They are still studied in our courses in elementary algebra and should not be confused with the permutations of group theory. The latter are often called substitutions to distinguish them from the former. This is still done in the recent Italian encyclopedia of elementary mathematics, to which we referred above, and has many advantages. The permutations or substitutions of group theory are dynamic,

while the permutations of elementary algebra are static. A. L. Cauchy used already the two terms permutations and substitutions in the former sense but he used the latter more frequently than the former and his example was commonly followed by later writers up to the time of H. Weber (1842–1913), who adopted the former term, and his popular algebras have been very influential in turning the tide in favor of this term at the present time. It remains to be seen whether this tide will return.

It should be emphasized that the extensive developments of abstract group theory are largely due to the great restrictions imposed on the combinations considered therein. While these restrictions are arbitrary in a certain sense it would be very far from the truth to assume that they were not suggested by concrete cases. Mathematics is largely the outgrowth of experiments and its abstract theories were often suggested by mathematical physics and were usually adopted very slowly in order to avoid endless repetitions or to simplify the developments. When the ancient Greeks assumed the Archimedian postulate and the closely related postulate that all right angles are equal to each other they probably did so to avoid the necessity of considering certain difficulties rather than to be in closer contact with actual facts. The assumption that curves intersect at the same angle as their tangents at their common points is a remarkable source of mathematical progress posterior to Euclid. If the simple mathematical considerations have led to such an extensive theory it is difficult to predict the scope our subject will assume when we pursue the study of the more difficult and less restricted ones.

In closing we desire to refer to a situation which concerns the professional mathematician less than those who are mainly interested in a bird's-eye view of this subject. The former incidentally secure a penetrating insight into the history of certain fields of mathematics and frequently pay little attention to the general histories of our subject in view of the fact that these histories contain too little relating to their special fields of study and this little is often in an unsatisfactory form. The professional mathematical historians have usually at best either familiarized themselves with some of the ancient or medieval manuscripts relating to very elementary developments of mathematics or culled from widely different sources the views of experts in various fields. The result is that the recent general histories of mathematics usually involve very flagrant shortcomings which could probably be most effectively reduced by a frank discussion thereof in the periodicals. The fact that this method has not always been available without friction results from an announcement in the preface of volume 2 of the oldest extant German mathematical periodical, as follows: "Everything that could injure someone will be unconditionally and rigorously excluded." Even in mathematical publications the truth has not always been paramount and probably never will be even if the Bible says "The truth shall make you free." Possibly the noted policy tends to explain the survival during more than a century of this particular mathematical periodical.

Those who recognize the large number of errors in some of our mathematical histories and are pained by the fact that so many young students as well as laymen are exposed thereto may find some consolation in the observation that most people absorb much more than they digest and what is not digested might almost as well be false as true. The trouble arises when we try to digest

falsehoods relating to scientific matters. The resulting pangs are usually not experienced until after the college days and even then they relate to only a small part of what has been absorbed. Most of us go through life with an undue respect for the printed page and the hope for improvement by evolution rather than by revolution. The laboratories and the mathematical demonstrations have rendered a great service towards freeing intellectual centers from some of their superstitions, but even in these centers the safe truths have as yet to be selected with care and the limits within which some others may be used safely constitute questions of tact.

Various efforts have been made recently to define the term mathematics, but these have naturally been no more successful than the description of an individual while it is still developing rapidly. One could perhaps convey a fairly accurate view by saying that Euclid's "Elements" represent ancient mathematics and that the large German mathematical encyclopedia now represents also modern mathematics, and one does not yet know what future mathematics will be. It is true that such a definition is of little value to those who desire to secure knowledge without personal effort, but to these we can only say that real knowledge usually does not come without such efforts. A large part of the rapid and somewhat burdensome growth of the modern scientific literature is due to an effort to construct automobile roads into the various fields of science, but many interesting details are apt to be overlooked in traveling these roads at the usual automobile speed. This is, however, characteristic of modern science.

# THE WORK OF THE BUREAU OF STANDARDS IN ELECTRICITY AND RADIO

By E. C. CRITTENDEN

CHIEF OF ELECTRICAL DIVISION, BUREAU OF STANDARDS

ELECTRICITY provides facilities essential to the modern social organism. Those facilities are created and maintained by a complex and highly organized industry, in which scientific control of product and scientific research looking to further development are most actively employed. In such control and development, precise and reliable measurements are necessary at every step. For workers in every exact science, electrical measurements have a double importance, because electricity not only provides light and power and communication, but also gives the most effective instruments for measurements of manifold kinds. To facilitate these measurements in science and in industry is the primary purpose of the electrical work done by the Bureau of Standards.

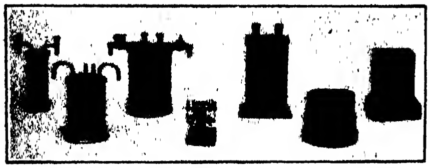
The Bureau as it exists to-day is, however, the result of 30 years of growth and adaptation to the needs and demands of the times, and its work takes a variety of forms which do not fit completely into any simple and logical classification. The various uses of electricity involve different kinds of service given by the Bureau, and its own activities are correspondingly diverse. It is possible here only to mention the more important of these activities and to give a few specific examples illustrating the work done.

## THE FOUNDATION OF ELECTRICAL MEASUREMENTS

Electrical measurements are based primarily upon mechanical forces. The methods used for deriving and defining the electrical units have varied, but the general intention has been to make the unit of electrical energy the same as that of mechanical energy, and in effect to measure electricity by the mechanical force exerted upon wires carrying electric currents in a magnetic field.

It is relatively easy to compare one electrical quantity with another, and such measurements can be made with a very high precision; it is, however, much more difficult to establish the correct values for electrical units in relation to the fundamental mechanical effects. Furthermore, the necessity of having uniform electrical units throughout the world has long been recognized because electrical measurements play so important a part in the world-wide interchange of scientific data as well as of industrial products. A series of congresses and conferences extending over a period of 30 years (from 1881 to 1910) therefore developed our present "international" system of units, which was intended to provide a uniform basis for electrical measurements approximately consistent with the mechanical units. This system of electrical units starts with an ohm, which is the resistance at 0° C. of a uniform thread of pure mercury 106.3 cm long and weighing 14.4521 grams, and an ampere, defined by specifying that it will deposit 1.118 milligrams of silver per second. In practise, however, the basic standards are wire resistance coils for the ohm and standard cells of prescribed electromotive force, and international agreement is maintained by comparisons of such standards.

The Bureau of Standards was created in 1901; for the first decade of its existence its electrical research work was largely directed to the establishment of



PRACTICAL STANDARDS OF RESISTANCE AND OF ELECTROMOTIVE FORCE

RESISTANCE COILS AND STANDARD CELLS OF THE TYPES SHOWN CONSTITUTE THE BASIS OF ALL PRECISE ELECTRICAL MEASUREMENTS. COILS ARE MOUNTED IN AIRTIGHT CASES; THE THREE SHOWN AT THE LEFT REPRESENT SUCCESSIVE STEPS IN DEVELOPMENT MADE AT THE BUREAU OF STANDARDS. THE SMALL CELL IN THE CENTER IS A SATURATED OR WESTON NORMAL CELL OF THE TYPE USED BY THE NATIONAL STANDARDIZING LABORATORIES TO MAINTAIN THE UNIT OF ELECTROMOTIVE FORCE, THE VOLT. THREE STANDARD CELLS OF THE UNSATURATED, PORTABLE TYPE, AS SUPPLIED COMMERCIALLY, ARE SHOWN AT THE RIGHT.

satisfactory basic units and the physical standards needed to maintain them. Under the leadership of Dr. Edward B. Rosa this experimental work rivaled that of the best European laboratories and gained such recognition that the final steps in the establishment of the international units were carried out at the Bureau by a committee including representatives from France, Germany and Great Britain. The system thus set up was put into use in 1912 and is still maintained through the cooperation of national laboratories in the larger countries. In this work the Bureau of Standards has taken a leading part; through the care exercised in the choice and use of its reference standards and the provision of larger numbers of them it has been more successful than any of the other laboratories in preserving stable values of the units.

With the establishment of such an international system of units on a basis presumed to be permanent this problem seemed to be settled; and other needs of more immediate urgency displaced further work on fundamental units for many years. It was, however, already known that the "international" electrical units were not so close to the true or "absolute" units as was originally supposed; the developments of modern physics and chemistry showed continually closer coordination of electrical and mechanical phenomena, and the necessity for using correction factors when the two were compared threatened to cause confusion in the future. Furthermore, increasing differences were found between the units used in different countries, while makers and users of precision apparatus were continually calling for greater and greater accuracy. It became evident, therefore, that the fundamental basis of electrical measurements must be reconsidered.

In the meantime, by an amendment to the treaty under which the International Committee and the International Bureau of Weights and Measures operate, those organizations were given jurisdiction over electrical units. An Advisory Committee on Electricity was formed in 1928, including the Bureau of Standards

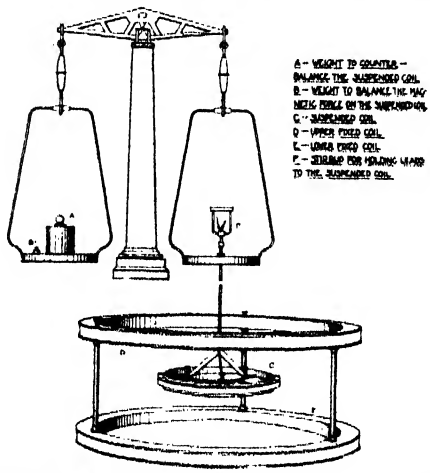



DIAGRAM SHOWING PRINCIPLE OF THE RAYLEIGH CURRENT BALANCE

AN ELECTRIC CURRENT FLOWING THROUGH THE COILS C, D AND E IS MEASURED BY WEIGHTS BALANCING THE ELECTROMAGNETIC FORCE EXERTED ON C.

THE CURRENT BALANCE AS ACTUALLY USED

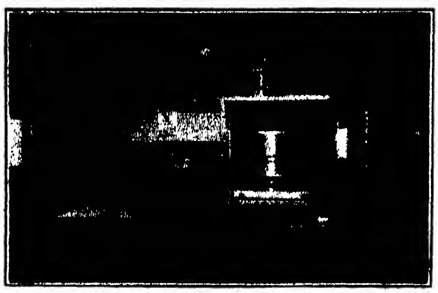
THE TWO FIXED COILS CAN BE SEEN IN THE LOWER CASE. THE MOVING COIL SUSPENDED FROM THE BALANCE ARM IS ENCLOSED. WEIGHINGS ARE MADE BY AN OBSERVER OUTSIDE THE ROOM THROUGH THE WINDOW AT THE LEFT.

and national laboratories of France, Germany, Great Britain, Japan and the U. S. S. R. (Russia). This committee decided unanimously that the electrical units should be revised as soon as new determinations of their absolute values could be made with sufficient certainty. Since that time the precise establishment of the ohm and ampere by absolute measurements has been one of the major research projects of the Bureau.

A determination of each unit by two different methods was planned. One determination of each unit is now nearly completed. Other laboratories are also making such measurements, and it is hoped to reach at least a preliminary international agreement at a meeting to be held in 1935. If possible, the new units will then be put into use in 1937.

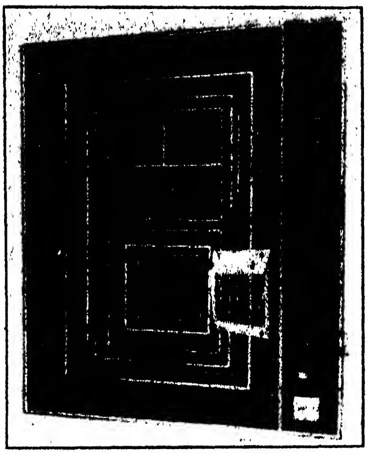
The principle applied in the absolute measurement of current is simple. Two parallel wires carrying current attract or repel each other. If the two wires are wound into coils of many turns, and one coil is hung from the arm of a balance, while the other is held above or below and parallel to the first, the electromagnetic force between the coils can be directly measured as an apparent change in the weight of the coil on the balance. A roughly approximate measurement of current can thus be made very readily, but when the final results must be correct to one or two thousandths of one per cent. innumerable difficulties arise. For example, the forces to be measured are only a few grams weight superposed on the weight of the coil. The actual weighings must therefore not have an error as great as one in ten millions; for such weighing uniformity of temperature about the balance is ordinarily considered essential, but in this case the current-carrying coils constitute a good electric heater which is necessarily placed near the balance.

The force also depends on the length of wire in the coils and on the effective distance between the coils. A direct determination of these quantities with the necessary precision would be almost impossible; this particular obstacle is



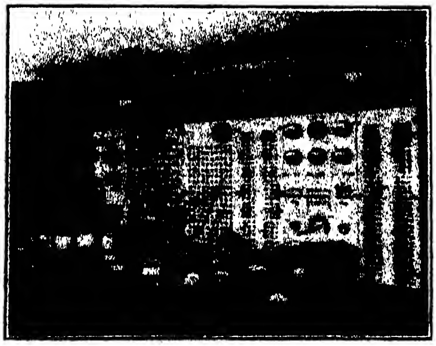
INDUCTANCE COIL USED IN DETERMINING THE MAGNITUDE OF THE OHM

THE COIL IS A SINGLE-LAYER WINDING ON A CAREFULLY PREPARED CYLINDER. ITS DIMENSIONS ARE MEASURED BY AN ELECTRICALLY CONTROLLED MICROMETER GAGE OPERATING INSIDE THE HEAT-INSULATED CHAMBER (SHOWN OPEN IN THE PHOTOGRAPH).



PIEZO-OSCILLATOR DEVELOPED BY BUREAU OF STANDARDS AS SEMI-PORTABLE STANDARD OF FREQUENCY

A QUARTZ PLATE OSCILLATING AT 100,000 CYCLES PER SECOND IS MAINTAINED AT CONSTANT TEMPERATURE AND BAROMETRIC PRESSURE. A TRIPLE TEMPERATURE CONTROL IS USED ABOUT THE NEST OF ENCLOSURES SHOWN OPEN IN THE PHOTOGRAPH. THE FREQUENCY OF THE OSCILLATOR IS THUS KEPT CONSTANT TO BETTER THAN A PART IN A MILLION.



ELECTRICAL INSTRUMENTS TESTED BY THE BUREAU OF STANDARDS

A TYPICAL COLLECTION OF INSTRUMENTS SUBMITTED FOR DETERMINATION OF THE ACCURACY OF THEIR CALIBRATIONS. IN THE BACKGROUND IS THE SWITCHBOARD THROUGH WHICH THE INSTRUMENT LABORATORY IS SUPPLIED WITH CURRENTS OF DIFFERENT VOLTAGE, FREQUENCY AND WAVE-FORM.

avoided by using two fixed coils between which the weighed coil is hung in such a way that only the relative sizes of the three coils need be known precisely. Their relative dimensions are determined by a separate series of measurements on the magnetic fields produced by the coils, but these measurements are so delicate that they can be made only when there are no magnetic disturbances. It has been possible to make them only by working after the street cars had stopped at night, and then only on nights when the earth's magnetic field was comparatively constant.

The difficulties cited are only a few of the many which require continual vigilance in such work. One by one these difficulties are overcome, but years are required to attain the necessary certainty in the final result.

The method which has been used to fix the absolute value of the ohm consists of several steps. First a single helix of wire with very uniform spacing is wound on a form which has been ground to be as perfect a cylinder as is practicable. Then the exact dimensions of the coil thus produced are measured, and from them the inductance of the coil is calculated in absolute units. The values of inductance thus found are carried over into units of resistance through measurements of a condenser, which is measured first with the inductance coil and then with standard resistance coils. The work thus summarized in a brief paragraph has required several years since special apparatus has had to be devised at every step and new formulas have had to be developed for the calculations.

While this experimental work on the fundamental units has been in progress, improvements have also been made in the practical standards which serve to maintain the units, that is, resistance coils and standard cells. A new type of standard resistor has been devised which has shown variations less than one tenth

of those to be expected with the best previous standards. Three such coils have made three trips to the European national laboratories during the past five years, and none of them has apparently changed more than two parts in a million. This type of coil therefore provides a highly dependable means for transferring values from one standardizing laboratory to another and for checking the instruments used in practical measurements.

In parallel with these laboratory developments the Bureau has carried on negotiations with the corresponding authorities abroad, and has developed in advance a plan for prompt establishment and dissemination of the new units as soon as the determinations now in progress here and abroad are completed. Provision has also been made for periodic comparisons of standards through the International Bureau of Weights and Measures, so that differences between the units of different countries will be detected and remedied. Incidentally this will, of course, give double assurance of the accuracy of our own standards.

### Electrical Standards for Practical Use

The establishment and maintenance of correct fundamental standards would be of little use without some provision for carrying over into practical measurements the units which they preserve; the provision of practical working standards is therefore a second essential function of the Bureau of Standards. Every electrical measuring instrument made in this country is calibrated by reference to standards certified by the Bureau; practically every meter by which electricity is sold in home or factory is not only thus calibrated originally by the maker, but is also retested periodically by the power company or the public service commission, both of which come back to the Bureau for certification of their reference standards; electric lamps of standard quality all go through a process of inspection involving continual tests with instruments kept in close agreement with the Bureau's standards; every important research and testing laboratory in this country depends upon the Bureau for verification of its electrical standards.

The starting point for all these measurements is the standard cell and the coil of one ohm resistance, but there are often many steps before the final result is reached. Precise resistance standards,

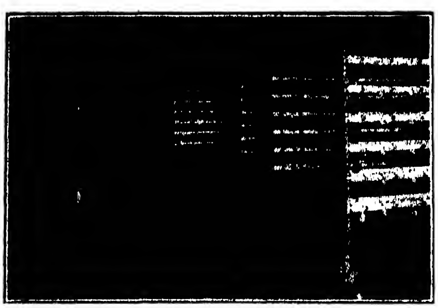
AN INSTRUMENT TOO LARGE FOR THE LABORATORY

The transformer shown was intended for use as a standard for measurements on a 132,000-volt system in California. Since the Bureau's high-voltage laboratory was too small to accommodate it, the transformer was tested by bringing connections out as shown.

for example, must cover the range from one thousandth of an ohm up to 100,000; potentials must be measured accurately from millivolts to hundreds of thousands of volts and at least estimated further out in the scale in microvolts or in millions; measurements must be made with alternating currents as well as di-

rect; inductance, capacitance and other effects arising from changing values of the current must be measured. The development of instruments suitable for all these measurements is, of course, a commercial problem, but besides furnishing the basic standards the Bureau is expected to be able to verify the final results. It receives, therefore, a great variety of instruments for test; the magnitude of this work arises from variety rather than number of instruments because the Bureau does not test electrical instruments on a wholesale basis. The work is largely limited to reference standards, instruments of special importance, or those involving difficulties or controversies such that calibrations by manufacturers or by other laboratories are not sufficient. However, even the tests of basic standards have grown to considerable numbers. Of standard cells alone more than 500 have recently been tested and certified in a single year. This practically equals the whole number handled in the first ten years of the Bureau's existence.

Continuous development of methods and apparatus is necessary to keep abreast of the expanding limits on the use of electricity in industry. When electricity is transported and delivered at 220,000 volts, its accurate measurement requires methods quite different from those used at low voltages of ordinary power supply. To assure the accuracy of its measurements at high voltage the Bureau is developing two independent methods of getting the results. The first is to start from ordinary voltages and build up to the high ones through combinations of standard transformers whose characteristics are carefully studied and whose circuits are designed to avoid errors due to electrical interaction between parts of the circuit and surrounding walls or other objects. The second method is to go back to fundamental principles and actually to weigh the force of attraction between disks charged up to the voltage which is to be measured. An absolute electrometer has been built for this purpose. Measurements with it are limited at present to 150,000 volts by the dimensions of the laboratory, but the electrometer will be capable of measuring up to 350,000 volts when sufficient space around it can be provided.



LIFE-TESTS OF ELECTRIC LAMPS

ON THE RACKS SHOWN LAMPS ARE BURNED TO DETERMINE WHETHER THEY GIVE THE LIFE AND THE EFFICIENCY REQUIRED BY THE SPECIFICATIONS UNDER WHICH THEY ARE PURCHASED BY THE GOVERNMENT. FROM 3,000 TO 4,000 SAMPLE LAMPS ARE THUS BURNED EACH YEAR; THESE SAMPLES ARE SELECTED FROM PURCHASES OF TWO TO THREE MILLION LAMPS.

In the measurement of large electric currents also, it has been necessary to devise special instruments in order to avoid errors arising from the large heating effects and the strong magnetic fields caused by such currents. The Bureau is now prepared to calibrate instruments up to 4,000 amperes on direct current and to 12,000 amperes alternating.

### Development of Special Instruments

While development of standards and special instruments is carried on primarily to meet the Bureau's own needs, a very important by-product is the improvement of apparatus for other purposes. For example, various types of resistance and inductance coils, galvanometers, potentiometers, transformer testing sets and magnetic testing appa-

ratus devised at the Bureau are widely used, and further improvements in such measuring apparatus are continually made available through cooperation with manufacturers of instruments.

More spectacular achievements may be cited in many cases where the experience of the Bureau's staff has been applied in fields outside its own regular work. For example, electrical instruments designed and built at the bureau to record the movements of heavy guns and the deformation of gun turrets have provided the basis for present design of such structures. Electrical gauges developed by the Bureau serve to record the strains in bridge members under live load, in mine hoisting ropes, in stays and structural members of airplanes and airships in flight and in the interior of massive concrete dams. The ships of the International Ice Patrol measure the salinity of the sea with electrical instruments designed and made at the Bureau of Standards. Studies of electromagnetic instruments at the Bureau have produced the best available seismometers for recording distant earthquakes, as well as the only instrument capable of giving a time record of the disturbances close to an earthquake center. Three of these were located in Long Beach and Los Angeles, and the records which they gave of the quake of March 10, 1933, provide a basis hitherto lacking for the design of buildings in such regions.

EQUIPMENT FOR TESTS OF DRY CELLS

TESTS OF DRY CELLS MUST SIMULATE SERVICE CONDITIONS, INCLUDING SPECIFIED PERIODS OF DISCHARGE WITH INTERVALS FOR RECUPERATION. APPARATUS DEVELOPED AT THE BUREAU CARRIES OUT THESE DISCHARGES AUTOMATICALLY ON HUNDREDS OF CELLS. THIS PARTIAL VIEW OF THE LABORATORY SHOWS RACKS OF CELLS AT THE LEFT, COUNTERS FOR RECORDING NUMBER OF DISCHARGES IN CENTER, AND A TELEPHONE SWITCHBOARD THROUGH WHICH INSTRUMENTS ARE EXPEDITIOUSLY CONNECTED TO THE VARIOUS CELLS WHEN MEASUREMENTS ON THEM ARE DUE.

### PROPERTIES OF MATERIALS

The electrical industry is particularly concerned with materials of three kinds; conductors, insulators and magnetic materials. Practically the only conductors used in large quantities are copper and aluminum. The Bureau has made exhaustive investigations of the properties of these materials, and has issued various compilations of data on them. For copper as commercially supplied a standard value of conductivity based largely upon the Bureau's results was adopted some years ago by the International Electrochemical Commission and is used throughout the world. With regard to aluminum, negotiations for a world-wide standard have not been concluded, but a standard conductivity based on the bureau's values has been adopted by the American Institute of Electrical Engineers and approved by the American Standards Association for use in this country. Conductivity of materials and methods of measuring it are now so well standardized that the chief service required of the Bureau is to check the accuracy of tests made in commercial practise. This is done, on request, by making precise measurements on standard rods or sample wires for comparison with the results obtained at the industrial plant or testing laboratory.

Magnetic materials (iron and steel) are not susceptible of standardization in the sense that conductors are, because they vary widely in composition and because their properties are affected so much by heat treatment and mechanical

USE OF THE EARTH-CURRENT METER
THIS INSTRUMENT DEVELOPED BY THE BUREAU OF STANDARDS MEASURES EITHER ELECTRICAL RESISTIVITY OF SOIL OR ELECTRICAL CURRENT FLOWING IN THE EARTH, AS, FOR EXAMPLE, FROM A PIPE SUBJECT TO DAMAGE BY ELECTROLYSIS. EXCAVATION AROUND THE PIPE IS NOT NECESSARY, SINCE THE MEASURING ELECTRODE CAN BE INSERTED INTO A DRIVEN HOLE AS SHOWN.

working. The Bureau's researches on these materials have therefore been largely directed toward the establishment of reliable methods for determining the magnetic characteristics of a given sample of material. Through cooperation with the American Society for Testing Materials various standard methods have been established and in this case also tests are made by the Bureau on request as checks on measurements made in commercial laboratories.

Measurements of the magnetic behavior of iron or steel sometimes gives important information about its mechanical properties. For example, forgings may thus be rapidly inspected for uniformity and freedom from flaws, but the relations between magnetic and mechanical properties are not simple. The Bureau has carried on a large part of the scientific work done to establish the applicability of magnetic testing methods for such purposes.

Electrical insulating materials are even more diverse and uncertain in character than magnetic materials. They include solids, liquids and even gases; and the properties desired depend largely on the place and the purpose for which the insulator is intended. The Bureau's work on insulators is largely research directed toward finding out why the materials behave as they do, since this is the first step toward making them better. This research at present consists chiefly of a study of rubber and rubber compounds and of very pure liquid insulators.

On electric lamps and batteries the Bureau regularly makes comprehensive tests, primarily to assure the quality of materials supplied on Government purchases. These tests include both efficiency or output of the devices and their life. They serve not only to determine the acceptability of materials supplied, but also to give information needed in periodic revisions of the Government specifications for these items. Incidentally also they have an important influence in promoting competition between makers on the basis of efficiency and real value of the product.

### ENGINEERING RESEARCH AND APPLICATIONS

In three distinct fields the Bureau of Standards has carried on a considerable amount of electrical work of an engineering type of which only the briefest mention can be made here. The Bureau's study of electrolysis by stray electric currents in the earth has resulted in improved methods and instruments for making electrolysis surveys, and its publications constitute the standard reference books on this subject; but, as a contribution even more important economically, it established the principle of settling such complex technical problems by cooperative scientific and engineering research rather than by legal arguments in the courts. Out of these studies also grew experimental tests of the corrosion of pipe materials in typical soils in all parts of the country, methods of predicting where corrosion

would be serious, and tests of protective coatings to reduce the loss due to corrosion. On account of the rapid growth in long pipe lines in recent years this general problem of corrosion in soils has overshadowed completely the special case of electrolysis.

Telephone service is an exceedingly important item in a business as large as the Federal Government; in recent years all important problems of telephone service in all departments have been referred to the Bureau of Standards for advice. It has been necessary not only to decide how to furnish service most economically and effectively in hundreds of new public buildings throughout the country, but also to choose special equipment for hospitals, prisons and other institutions. The net result has been that the telephone engineering group of the Bureau has spent all its time on these government problems, but the amounts directly saved to the Government thereby have been many times the cost of this service.

The third type of engineering activity is the development of codes of practise in industry, especially those affecting safety of persons. The Bureau took a leading part in organizing this work on a national scale under the procedure of the American Standards Association; this gives the authority and responsibility for all decisions on technical questions to committees representing all organized interests concerned in the code. The outstanding example of the Bureau's work in this field is the National Electrical Safety Code, a very complete set of rules to be observed in the generation, distribution and use of electric power, in order to make the service as free as possible from hazards to persons.

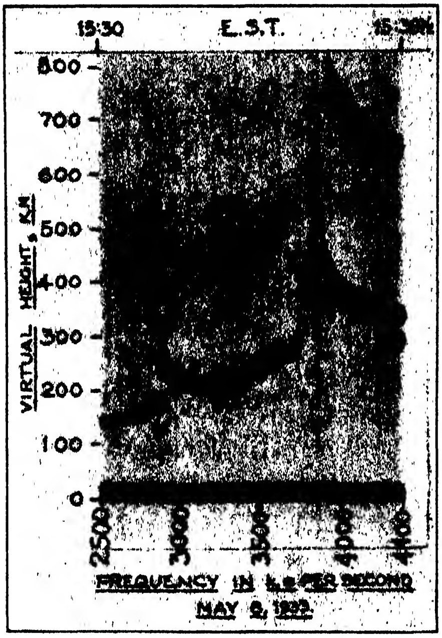
## Radio Measurements and Standards

Radio communication is simply an application of oscillating electric currents and electric fields, but their rapid oscillation introduces new problems of measurement which have become more and more difficult as the range of frequencies used has been pushed upward. In mechanics, Newton's laws seemed adequate and exact as long as one dealt with velocities of moderate value, but in the newer physics the behavior of particles moving with much greater speeds has given rise to a new and more complicated science of mechanics. Similarly, radio has its own technique of measurement in which effects negligible in ordinary electrical measurements become the most important factors.

A large part of the Bureau's work in radio has been intended to supply to this new industry the necessary methods of measurement and information on the behavior of devices and materials in rapidly alternating electric fields. Methods

RECORDERS DESIGNED BY BUREAU OF STANDARDS TO MEASURE THE INTENSITY OF RECEIVED RADIO WAVES

THREE RECEIVING SETS WITH AUXILIARY APPARATUS AND RECORDING MECHANISM MAKING CONTINUOUS RECORD PROVIDE DATA FOR STUDY OF RADIO FADING, INTENSITY VARIATIONS, ATMOSPHERIC DISTURBANCES AND CORRELATIONS WITH SOLAR AND MAGNETIC PHENOMENA.




CHARACTERISTICS OF IONIZED LAYERS OF UPPER ATMOSPHERE DETERMINED BY RADIO MEASUREMENTS

RADIO SIGNALS ARE REFLECTED BACK TO EARTH BY THESE IONIZED LAYERS. AN AUTOMATIC APPARATUS DEVELOPED BY THE BUREAU OF STANDARDS RECORDS THE LAYER HEIGHT AS A FUNCTION OF FREQUENCY. THREE DISTINCT LAYERS ARE ILLUSTRATED, CALLED THE E, $F_1$ AND $F_2$ LAYERS. FROM THE CRITICAL FREQUENCIES, $f_E$ AND $f_{F_1}$, AT WHICH A CHANGE IS SHOWN FROM ONE LAYER TO ANOTHER, THE IONIZATION IS CALCULATED.

and instruments have been developed for measuring radio currents and resistances, signal strength and power lost in insulators. Condensers and coils adapted to radio frequencies have been designed. Properties of electron tubes, antennas of various forms and insulating materials have been studied. However, with increasing demands for the use of radio in different services, the most pressing problem has become that of accurate measurement of frequencies, because the effective use of the available radio spectrum depends upon precise control of the frequency used by each station. Consequently the Bureau's work on radio measurements is now largely concentrated on the development and maintenance of exact standards of frequency.

In recent years most remarkable precision has been attained in such standards by using oscillating plates of crystal quartz. In this material, mechanical pressures and electric fields are so related through the piezo-electric effect that the plates can be set into vibration by alternating fields and in turn the natural frequency of vibration of a plate can be made to control the currents in a suitable circuit. Many laboratories have contributed to the development of devices using this principle. By making full use of the work of others and adding refinements, the Bureau has built, and operates continuously, a set of standards which supply radio frequencies accurate to a few parts in 100,000,000. To attain this accuracy four independent piezo-oscillators are used, each in a double thermostated chamber and each supplied with electric drive which is most carefully controlled. Each oscillator is adjusted approximately to 100,000 cycles per second, continuous records are made of the beats arising from differences in frequency of the four oscillators and the actual frequencies are determined by comparison with corrected standard time signals over a considerable period. Frequencies higher and lower than that of the primary standard, and of practically equal accuracy, are furnished continuously by using multiples and submultiples of that frequency.

In order to make its own accurate standards widely useful, while keeping down to reasonable limits the routine testing demanded of it, the Bureau began ten years ago to transmit signals of specified standard frequencies. Such signals are now sent out at regular intervals on a frequency of precisely 5,000,000 cycles per second. A 30-kilo-

watt transmitter installed in April, 1933, is expected to make this service directly usable throughout the United States. Incidentally, it will also make possible direct comparisons with European laboratories, which are important on account of the world-wide effects of some radio transmissions.

### Propagation of Radio Waves

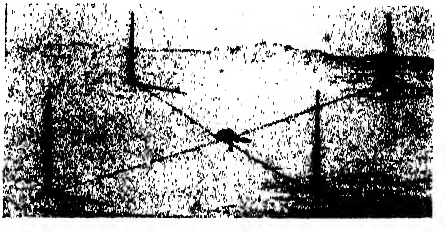
The proper distribution of the radio spectrum among different services requires a knowledge of the distance range attainable and the dependability of transmission with different frequencies. Phenomena of transmission also affect vitally such services as radio compasses and radio beacons. A second large division of the Bureau's work is therefore the study of behavior of waves between transmitter and receiver. The results of this work have been of the utmost value in the allocation of frequencies and the spacing of stations both in this country and throughout the world.

It is well known that long-distance radio is possible only because the upper region of the atmosphere is ionized and therefore constitutes an electrical conductor (Kennelly-Heaviside layer) which refracts or reflects waves back to the earth. In recent years, however, it has been discovered that the conducting layers are manifold and complex and are continually changing, so that waves of various frequencies are reflected quite differently at different times. The Bureau of Standards takes a leading part in a systematic study of these effects which is being carried on throughout the world through the International Scientific Radio Union. Instruments have been devised which make continuous records of the heights of the conducting layers which are effective in reflecting waves of various frequencies and of the variations in strength of the signals received from distant stations. Besides their use in the fundamental studies. such instruments find many immediate practical applications, such as observations on broadcasting stations attempting to operate in synchronism.

### Radio Devices and Applications

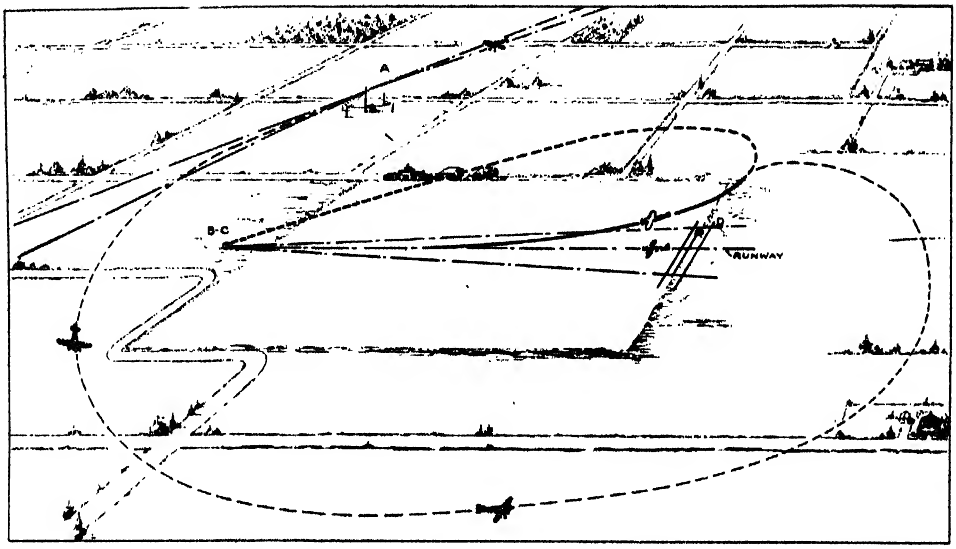
While the Bureau's own responsibilities lie in the field of measurement, standards and fundamental research, it is frequently called upon by other Government agencies to devise apparatus for their use. So, for example, when the Air Mail was inaugurated, the Bureau of Standards was called upon to develop radio sets for planes; the Bureau began broadcasting market reports for the Department of Agriculture before commercial broadcasting was established and helped in the development of sets for receiving them; it devised the original models of all the several systems for radio direction finding later used and further developed by the Navy, the Lighthouse Service, the Army Air Service and finally the airways of the Department of Commerce. The latter systems use directive beacons which indicate to a pilot whether he is on or off his course by signals received on an ordinary radio set.

When the Aeronautic Branch of the Department of Commerce was estab-



AIRWAY RADIO BEACON STATION USING TL (TRANSMISSION-LINE) ANTENNA

THIS RECENT DEVELOPMENT OF THE BUREAU OF STANDARDS ELIMINATES ERRORS IN INDICATED COURSES OF THE AIRWAYS RADIO BEACONS WHICH ARE CAUSED BY HORIZONTALLY POLARIZED COMPONENTS IN THE TRANSMITTED WAVES FROM LOOP ANTENNAS. A SPECIAL TYPE OF TRANSMISSION LINE CONNECTS THE TRANSMITTER WITH EACH VERTICAL ANTENNA SO THAT NO HORIZONTAL PART OF THE SYSTEM RADIATES.




SKETCH OF BUREAU OF STANDARDS SYSTEM OF RADIO AIDS FOR BLIND LANDING OF AIRPLANES

AFTER BEING GUIDED TO THE VICINITY OF THE LANDING FIELD BY THE RADIO BEACON A, THE PILOT RECEIVES LATERAL GUIDANCE ALONG THE LANDING RUNWAY BY A RUNWAY BEACON B AND VERTICAL GUIDANCE BY THE LANDING BEAM PRODUCED BY A TRANSMITTER C. HE RECEIVES INFORMATION OF LOCATION LONGITUDINALLY WHILE LANDING BY SIGNALS FROM MARKER BEACONS D. THE SYSTEM IS INSTALLED AT THE NEWARK, N. J., AIRPORT.

lished, the Bureau of Standards was designated by law to carry on research for it, and in this connection has developed many improvements in the directive radio beacon. These include instruments to give the pilot a visual indication of his position instead of the signals formerly received only by ear, combined transmitters to keep up simultaneously telephone communication with the same receiving set which serves for the beacon signals, a shielding system to prevent the engine ignition from interfering with radio reception, methods of adjusting the several courses of one beacon so as to serve airways converging at various angles, and special transmitting antennas which greatly reduce the errors in course indications previously experienced at night.

The development most recently carried to a practical stage is a complete system for blind landing of aircraft. Equipment of this type was installed at the Newark (N. J.) Municipal Airport early this year. The practicability of the system has been demonstrated by numerous landings in a hooded cockpit and also under fog conditions which interrupted all scheduled flying over a wide-spread area, including the Newark Airport. The tests included a completely blind flight in dense fog from College Park, Maryland, to Newark Airport during which the ground was entirely hidden until the plane was within about 2,000 feet of Newark Airport at an altitude of somewhat over 100 feet. A brief description of this system of flying aids which makes such flights possible was published in the SCIENTIFIC MONTHLY for July, 1933, p. 94.

# HOHOKAM: A CHAPTER IN THE HISTORY OF RED-ON-BUFF CULTURE OF ARIZONA

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## INTRODUCTION

WILLIAM MARDON, of Bisbee, Arizona, who has been interested in archeology for a number of years, discovered the campsites in 1929, and since then he has found many things of interest, all of which will be described in this article. He has done a great deal of digging and has unearthed really worth-while finds. To him belongs the credit of discovery.

The writer became interested in the ancient communities in 1930 and took the photos, copied the designs of the pottery, made the sketches of the hearths and has tried to digest the current opinions of archeologists regarding the Hohokam with the idea of applying them to the Red-on-Buff campsites under discussion.

Many of the ideas advanced in this paper are based on observations and deductions of Mr. Mardon and the writer and were formed from evidence seen on the ground. Much work still remains to be done and this will continue as time is found for it. We are indebted to the well-known archeologists, Dean Byron Cummings, of the Arizona State Museum at the University of Arizona at Tucson, and Dr. H. S. Gladwin, of Gila Pueblo near Globe, Arizona, for information, helpful suggestions and encouragement in the work. Mr. Wm. Stevenson kindly gave permission to excavate the campsites which are on his ranch.

The Gila Basin of Arizona, which now is the location of many peaceful agricultural settlements and the scene of industrious mining operations, was at one time the stage of romantic Spanish adventures and gruesome massacres by Apache Indians. However, long before that, men lived here in large communities. They left no written history, but from their handiwork and the tree rings[1] of the poles of their dwellings and the charcoal of their fires, the story is gradually being put together. But even before these times, in the Pleistocene, 20,000 to 30,000 years ago, when now extinct species of the mammoth, the mastodon, the bison and the horse roamed these plains, men lived here, as attested by the finding of an arrow-head in the matrix surrounding the bones of such an animal in near-by New Mexico, and the finding of crude stone implements of human manufacture and use and a fireplace in a stratum 15 feet below the surface, near Bisbee, Arizona. In the same stratum were found bones of extinct species of bison and horse and in a stratum 5½ feet above was uncovered the head of a mammoth.

It is believed that, about 200 B. C., a race of people came up the west coast of Mexico, and in the earlier periods of the culture drifted as far north as the Verde River and Tonto Creek. Later, they became sedentary along the Gila River and its tributaries. These people raised corn and made pottery. The corn was small and quite a different product from the one which present-day Americans raise. They cremated their dead and knew a great deal about irrigation. They were a remarkable people, peaceable, intelligent, and hard workers.

A great drought, lasting from 1276 to 1299, was probably one of the causes that made them move about searching

[1] A. E. Douglass, *National Geographic Magazine*, December, 1929.

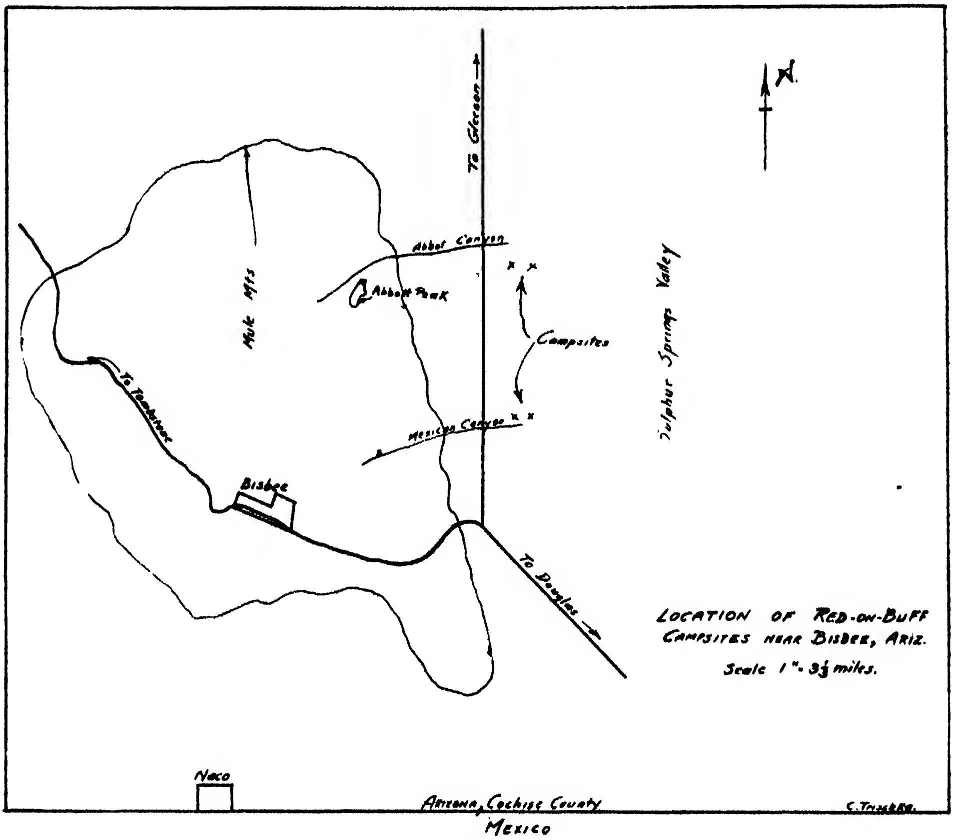


FIG. 1

FIG. 2. LARGE BOWL WHICH CONTAINED CHARRED SUNFLOWER SEEDS

for water; and, not finding it in the area of Arizona, they finally left the country and drifted south, eventually, perhaps, becoming one of many tribes that were ruling Mexico when Cortez came to America. Some of them, however, remained, and the Papago and Pima Indians of Arizona may be their descendants. These people called them the Hohokam or "Ancient Ones," and the name "Hohokam" has been recently given them by archeologists.

The most characteristic artifact is their pottery, which they developed through four or five stages from very poor unslipped material to well-slipped, highly decorated and polished work. It seems strange that their product later reverted back again through decadence to a poorer quality. Throughout this development, the background of the decorated pottery was buff and the painting on it red, hence the name "Red-on-Buff."

These people had neighbors of various kinds, some of whom no doubt found these peaceable agriculturists easy victims. To the north lived the Puebloans, who built cliff dwellings and two or more storied pueblos, in which the ladies reigned supreme. To the east were the Mimbres people, whose black-on-white pottery is very attractive and who acted as a barrier against the warlike plains tribes. To the south were various Mexican cultures, about which very little is known, and to the west were the Yumas, who in their early development were more warlike than later.

While these people and most of their neighbors were sedentary, architecturally inclined, and tilled the land, the ancestors of many of us were wild unconquered hordes of rather low order of intelligence who built the great stone monuments of England and formed the Middens on the Danish and Scandinavian coasts. The Hohokam culture, though neolithic, was a remarkable one and one wonders what would have been their fate had they had the advantage of ancient contacts with the far advanced state of civilization to the south, as did our ancestors in their contacts with Rome, Greece and Egypt. Why did they degenerate? What finally became of them?

In Arizona there are three well-equipped and earnest groups of archeologists who are doing much to unravel the now popular puzzle of the ancients

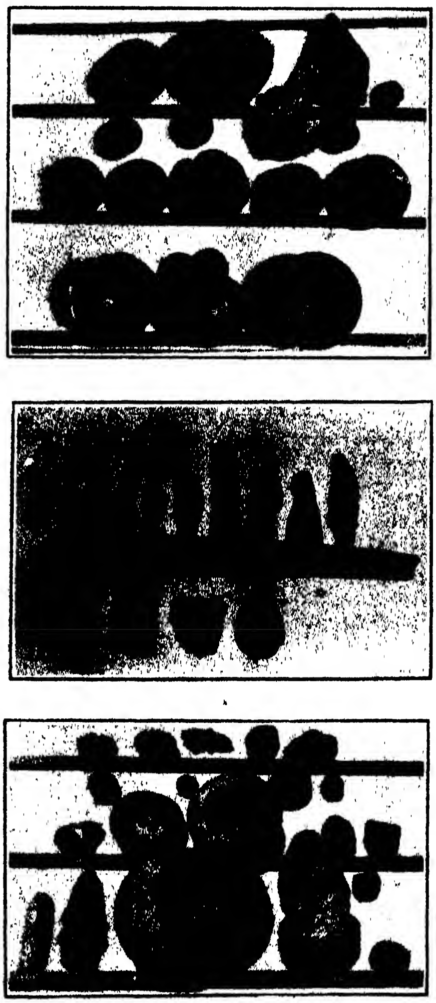

FIG. 3. ARTICLES FOUND IN CAMP SITES
*Upper:* RED-ON-BUFF POTTERY. *Middle:* STONE PICKS, COMBS, KNIVES AND SCRAPERS. *Lower:* STONE MORTARS AND AXES.

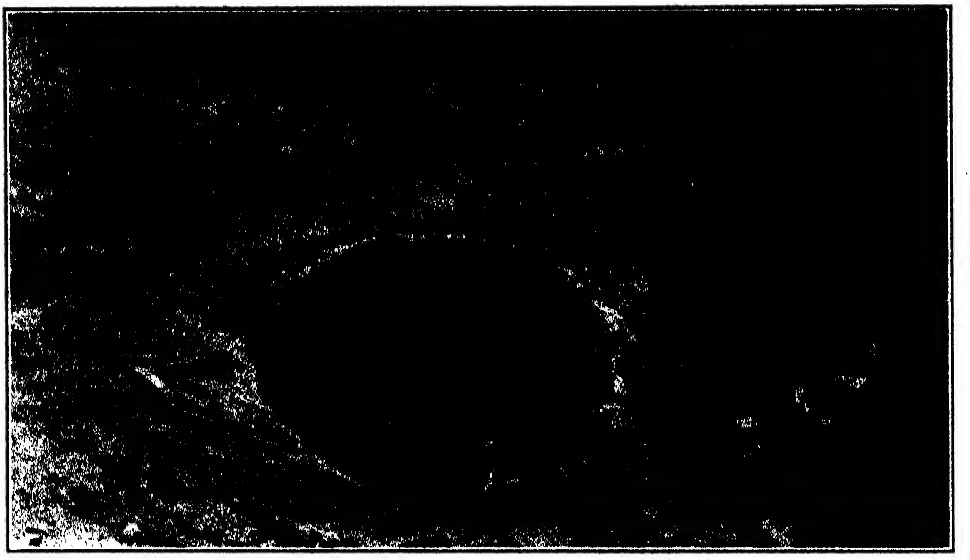

FIG. 4 (a). HEARTH, TYPE 1
SKELETON ON ROCKS. ACCIDENTAL BURIAL VAULT.

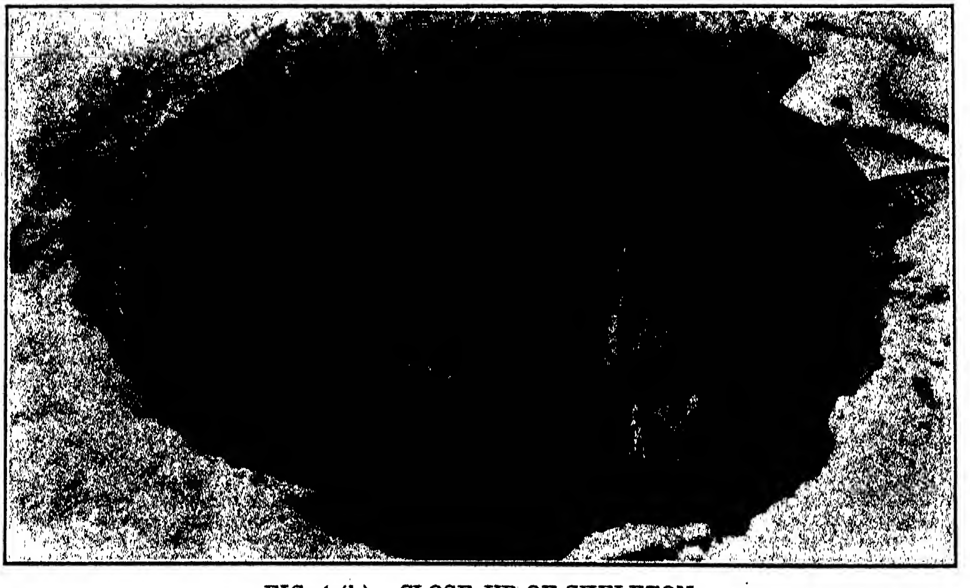

FIG. 4 (b). CLOSE-UP OF SKELETON
SHOWING CUPPED HANDS AND DRAWN-UP LEGS.

of the Southwest. They are at the Arizona State Museum at the University of Arizona, Tucson; the Gila Pueblo, near Globe, and the Northern Arizona Museum, at Flagstaff. It is a problem that not only takes the best of talent but demands patient and continued interest. Arizona is fortunate in having these able people to work on its ancient history, and they are making excellent progress.

The pictures shown here are of things made by the Red-on-Buff people in an area eighteen miles long and four miles wide. They came to this country perhaps empty-handed as far as artifacts are concerned, but with ideas about things and some knowledge of the arts. They had corn, squash, sunflower and other seeds, but found in the country many native fruits, such as mesquite beans, piñons and acorns. Of game there probably was plenty, and a living was gotten comparatively easily. They had no metal, but out of and with rock they fashioned everything they needed. Imagine yourself put to the necessity of doing this!

These people were sedentary and soon established themselves wherever there was water for irrigating, good soil for farming, clay for pottery and rocks fit for their uses. There were many such sites in the Southwest. They were soon settled and content, and it can be imagined that they were superstitious and on this account sometimes would change their location on short notice. They had no horses, sheep or other domestic animals, except perhaps dogs and turkeys. Before they made pottery, they made vessels out of various kinds of rock. They were truly a Stone Age people.

Every Red-on-Buff site represents a chapter in the history of the story of their development and only after a great deal of work (actual digging) and research among records of previous finds, as well as a close study of pottery and the remains left in the camps, is it possible to reconstruct a part of the chapter; much will never be known, because perishable artifacts are destroyed, and they left no written history, except the pictographs of the cliffs.

FIG. 4 (c). AFTER REMOVAL OF SKELETON

ROCKS AND ASHES WERE FOUND IN THIS FIRST HEARTH BOTTOM WITH ITS DOUGHNUT-LIKE PATTERN.

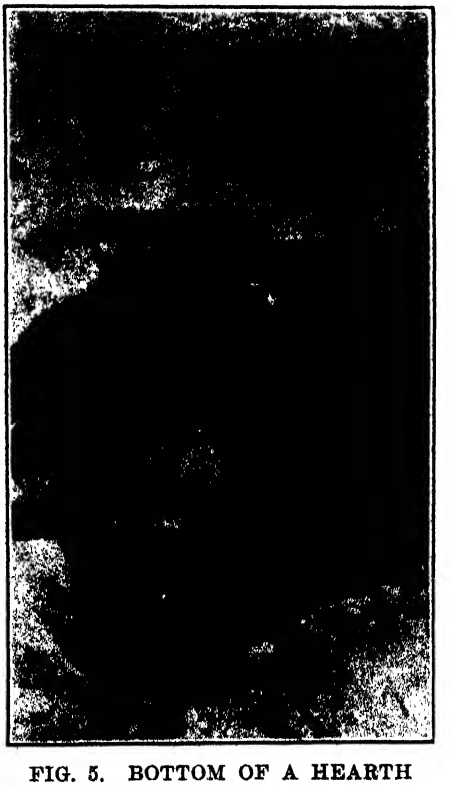

FIG. 5. BOTTOM OF A HEARTH

THIS WAS DUG IN THE STREAM OR CREEK BOULDERS. SANDY TOP SOIL MADE A SMOOTH CONTACT WITH THE LAYER OF BOULDERS.

FIG. 6. THE HEARTH WALLS

ON DIGGING ON THE OUTSIDE OF THE WALLS IT WAS FOUND THAT THEY CONSISTED OF 3 TO 4 INCHES OF RED BAKED CLAY OR ADOBE AND THAT THIS CLAY HAD BEEN DAUBED ON AFTER THE HOLE, WHICH WAS OF AN OLLA-LIKE SHAPE, HAD BEEN DUG.

An abundance of broken arrowheads, as well as chipped or flaked pieces of rock in a definite locality, leads one to believe that this is a place where these objects were formed. The same is true of pottery and carved stone bowls and gouged pots. It is probably going too far to suggest that there was a Main Street with its various business sections, as we find in the large modern cities today, but if the segregation of various artifacts in definite places can be used as criteria, this comparison is not too far-fetched.

The camps and the things found there, about to be described, are located on the eastern slope of the Mule Mountains, Cochise County, Arizona, and

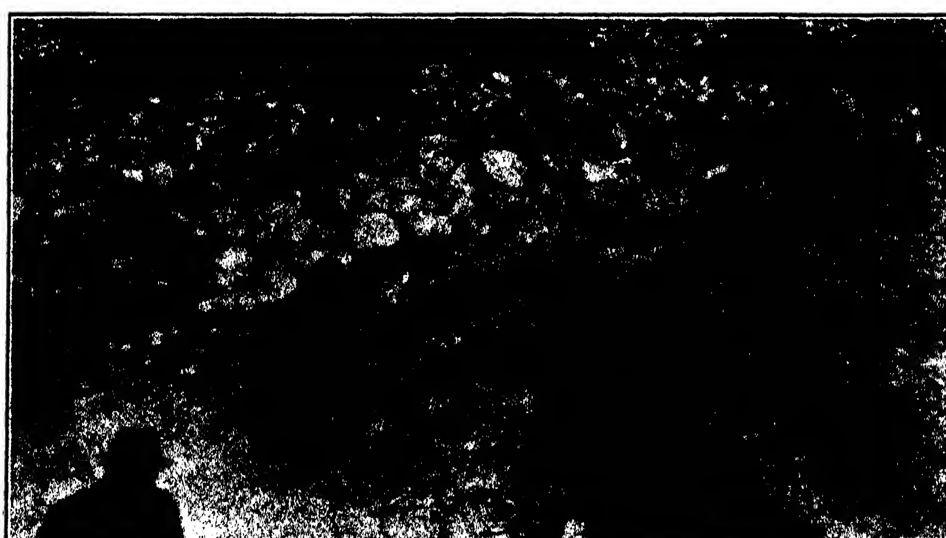

FIG. 7. HEARTH IN CENTER OF ROCK WALLS OF DWELLING

located from ten to fourteen miles from Bisbee (Fig. 1).

The first thing noticeable about the campsites is the abundance of pottery fragments. Many of them are undecorated; others show red painting on a buff background, and only occasional black on white, which came from the Mimbres, neighbors to the east. A very few small fragments of incised and coiled pottery have also been found. Trading with their neighbors must have gone on, or conquest, since sea-shell bracelets as well as different kinds of pottery other than that of their own manufacture are found in pure Red-on-Buff campsites.

Their pottery is painted on the inside, if it is dish-like, or on the outside, if it is bowl or olla-like, and in the latter case it is often beautifully polished on the inside to a smooth, black, satiny finish after having been smudged. Some bowls are painted both outside and in. It seems likely that the painted ware was their great pride and was used for show purposes and for food, either at meal times or for storage of grains.

There is also a great deal of pottery which is undecorated and unslipped which was used for water ollas and as storage for the various edible seeds (Fig. 2). Some of these were quite thick and heavy and were perhaps used for cooking because signs of fire, other than that due to the original firing, is seen. Much of the undecorated pottery is smudged, that is, blackened by carbon during the firing process and then polished.

Their main pottery was of four general shapes; a dish to eat out of, an olla to carry water, a bowl to store things in and a dish or scoop for transferring food from the dish to their mouths. The illustrations (Fig. 3) show the general types of the decorated tableware. After cremating their dead, they took the ashes and put them in one of the food bowls, placed an olla inside of this and the scoop over the top or to one side of the olla. These cremation sets, made especially for this purpose, were smaller than the regular pottery and were undecorated. This combination and its contents were then buried. The photos

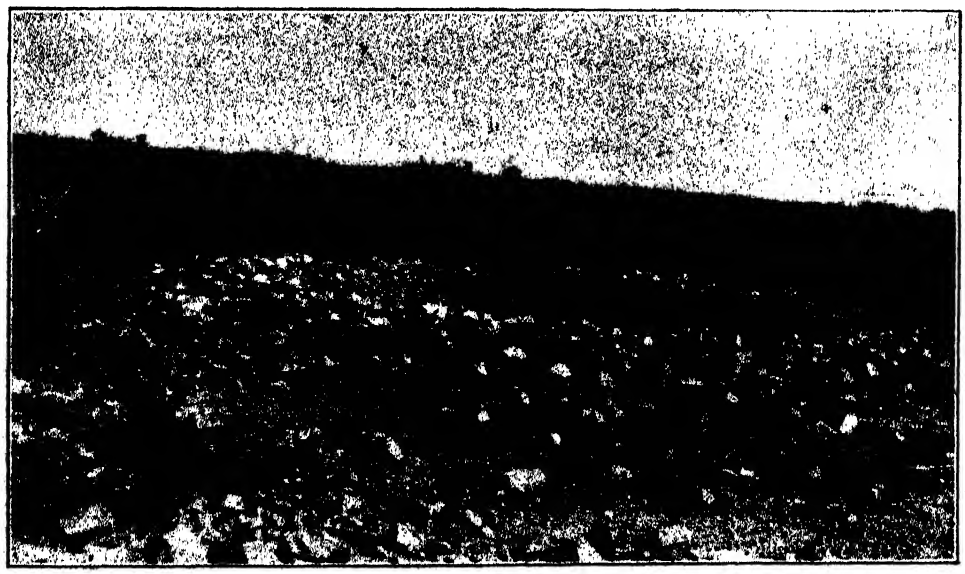

FIG. 8. CIRCULAR OUTLINES OF FALLEN WALLS OF HOUSES OF RED-ON-BUFF CULTURE

show two sets of cremation bowls with the contents undisturbed. The ollas of largest size were most commonly of heavy unslipped pottery and unpainted. Practically all the ollas were rounded at the bottom and were probably suspended or partially buried, as they could not stand alone, while others had the Gila shoulder bottom which has a semi-rounded bottom and stands without support in a tilted position.

Pottery markers, circular in shape and an inch or more in diameter, are common, indicating the possibility that they played games. A handful of evenly matched almost round stones suggests marbles. In common with other primitive people they no doubt played many games.

The second thing which is noticeable is the abundance of work these people must have done besides the making of pottery, for there are rocks of all kinds and shapes which have been chipped, ground, whetted, flaked, bored or worn to a flat or curved surface.

There are metates or corn grinders, ground or gouged stone mortars, flat, long and narrow stone knives, stone combs, stone nose, ear and finger rings, arrow-heads of rhyolite, quartz, schist and greenstone, and chert, paint-mixing slabs and pots, both gouged and ground, chipping or mano stones, prayer rings, carved Gila monster, picks for digging, turquoise and stone beads, grinding stones for metates and for polishing pottery, boring stones for making holes in various beads, hammer stones, stone axes and stones that have been marked for purposes unknown (Fig. 3).

The metates are generally of granite and beside the small groove some have round cup-shaped depressions, indicating that they not only ground by rubbing but by using a long rock held vertically and rotating it on its long axis.

Of the stone implements, the combs (Fig. 3) are of greatest interest because they are not found elsewhere and because of the problem as to their use.

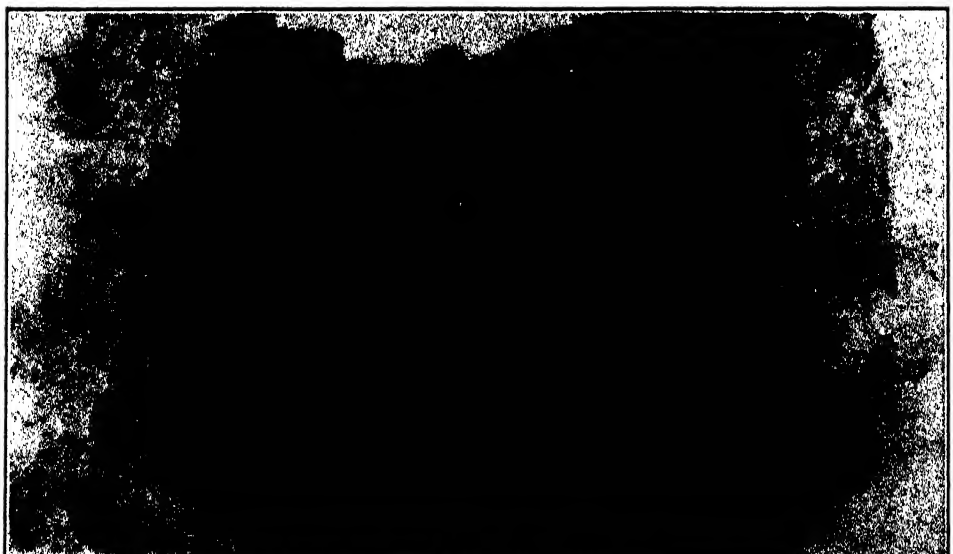

FIG. 9. BOTTOM OF A HEARTH

AFTER REMOVAL OF WALL TO SHOW THE SEVEN 18″ TO 2′ 0″ DEEP OUTER HOLES AND THE LARGER 2′ 0″ DEEP CENTER HOLE. NOTE: OUTER HOLES SLANT OUTWARD FROM CENTER AT ANGLE OF 70°.

FIG. 10. FLOOR OF DWELLING

SHOWING SHOULDER ON WHICH THE STONE WALLS WERE ERECTED.

They may have been used in combing the hair of humans, but they would have been of considerable use in combing the seed from cotton which they probably wove into clothing, for cotton grows native in Arizona. The combs are of red shaley sandstone, which could be flaked easily to a thin, wide shape and then smoothed into shape, or of a fine-grained, greenish colored sandstone or quartzite, which was formed into its shape with other rocks. In both kinds, the teeth were cut into the edge by using narrow, sharp-edged, harder rocks, as we use a file, and in all of them handles were shaped by chipping and grinding. They seem rather crude to us, but considering the material they had to make them out of and with, they did a very creditable piece of work.

The knives (Fig. 3) are of the same red, shaley sandstone and thinner than the combs. They were used for cutting meat, in skinning animals, preparing hides for tanning and many other purposes. Similar flat rocks without handles were used for scraping. The axes were used mostly for smashing and breaking purposes either on wood or stone, but one of them which is most beautifully symmetrical and is not a Red-on-Buff ax was probably used for ceremonial purposes. Except for the size of one of the axes, which weighed 19½ pounds, there is nothing unusual about them.

Bits of bright-colored stone, quartz crystals, unusually shaped stones and fossils are found in considerable number and lead to the belief that they were carried to camp for their unusualness, out of curiosity or as charms. But in the case of the quartz crystals it is noticed that all the points are worn off, indicating that they had been used for boring and carving.

Beads of turquoise of small size and having small holes, while not common and somewhat bleached by the sun, have been found. These stones probably came from the turquoise mines fifteen miles north of the campsites at Gleeson, Arizona. A small pendant of turquoise representing a frog had a hole bored in its head and was probably worn as a charm.

There are well-shaped, smoothly polished ear, nose and finger rings, made

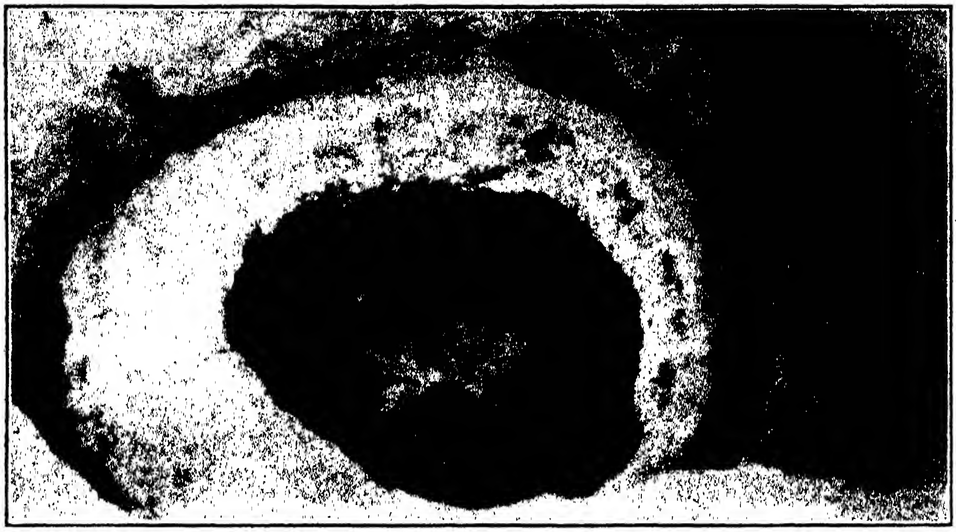

FIG. 11. A TYPE 7 HEARTH
SHOWING PARTIAL VIEW OF THE BOTTOM.

of a greenish shaley rock. The ear and nose rings were left with an opening, so that they could be worn without piercing the nose or ears.

The stone pots (Fig. 3) are smaller than those of pottery and were made either of sandstone or the softer more easily worked solidified lava mud from the southern foothills of the Chiricahua Mountains to the southeast. The latter are called gouged pots and were mostly shallow and very likely held paint which was used to decorate humans and pottery. They would be convenient also for lamps, the grinding of spices and for holding the fine clays used as slip on the pottery and many other purposes. From the illustrations (Fig. 3) it will be seen that they made most of these stone pots symmetrical in shape.

A stone pot, which shows their love for the unusual as well as their artistic ability, represents a lizard, Gila monster or some other kind of reptile and in its back is a depression similar to that found in their gouged pots (Fig. 3). The gouged pots were made by driving three or four slanting holes toward a common center and prying out the rock, leaving the desired depression, which was finally formed by chipping and rubbing down the rough surface, and since the solidified lava mud is quite soft, this was done easily with harder rocks. A prayer ring and various borders were made of a pumice-like lava. Prayer rings were used in addressing the water spirit of the earth.

Many of the manos, chipping stones and grinding rocks were made of fine-grained silicified sandstone, though schist, quartz, rhyolite, vesicular flow rock were used for metates, or milling stones, and had to be carried into their camps, since it is not found as float. Manos and broken or well-worn metates are very common. The well-used manos are rounded, but they are sharply angular when first made.

The arrow-heads show very fine workmanship, and many of their arrow-head-like borers are really works of art. Arrows were made by chipping or flaking with other harder rocks. Arrow-heads are not plentiful in the camps, but chips of all sorts with various kinds of edges

are common and were no doubt used for various purposes as knives, scrapers, borers, etc.

These people show a surprising stage of mental development, in spite of their living in the stone age, as is manifest by the number of conveniences employed. Their ingenuity is admirable, and they led happy, contented and useful lives.

### Circular Pit-Hearth Houses

The most interesting features of these campsites are the hearths. In 1929, Mr. Mardon first discovered the camps and contented himself with looking for and finding artifacts. In the latter part of 1930, he found a segment of baked adobe projecting out of the ground and on digging found it to be part of what

FIG. 12. SKELETON IN TYPE 7 HEARTH

From the position of this skeleton it would appear that the body was thrown in and covered with rocks.

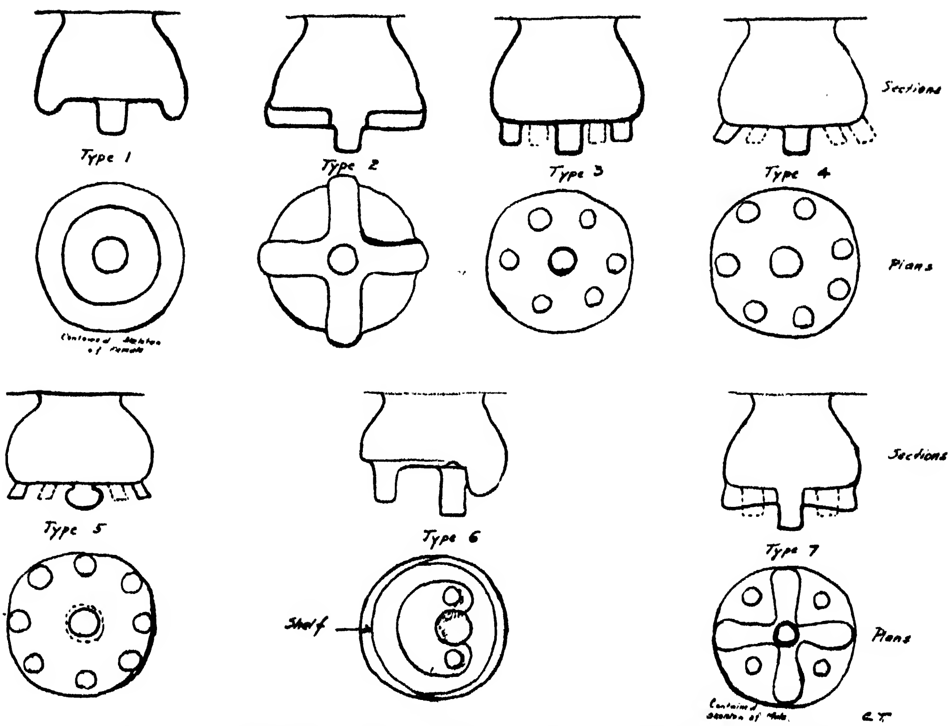


FIG. 13. SECTIONS AND PLANS OF RED-ON-BUFF HEARTHS IN CIRCULAR PIT HOUSES

appeared to be the grand-daddy of all ollas; but digging inside of it, there was disclosed a human female skeleton as shown in Fig. 4, Type No. 1. No, it was not an olla but a burial vault. That seemed certain; and then after the skeleton was removed, the hearth, Type No. 1, was disclosed, but even then it was not recognized for what it was, because the stones of the dwelling wall had been washed away (see Figs. 4 and 5).

In uncovering the hearth, Type No. 2 (Fig. 7), a segment of the stone wall was noticed, although it was originally found by the aid of the slightly projecting baked adobe of the hearth. No skeleton was found, but it had the eighteen to twenty-inch layer of stones on the hearth as did the first one and the three to four inches of baked adobe mud as walls.

The circular arrangement of stones had been noted in the camps before (page 423), but was considered as being the remains of ancient tanques or cisterns for catching and storing water. Digging in the center of these circles of stones disclosed the remaining hearths shown herewith. All the hearths are in the center of what were at one time circular stone dwellings, which were twenty to thirty feet in diameter, and they extended three to five feet below the level of the floor of the dwelling.

Only one other skeleton, the skull of which is shown, was found in the hearths, and thus far seven distinct patterns of hearth bottoms have been found. Photos and sketches of these are given herewith (Figs. 4–13, inclusive).

All of them are smaller at the top, three feet to four feet across and wider at the bottom and olla-rim shaped at the top. They suggest a large buried olla.

In making the hearth, a hole was dug, having the shape of the hearth, and then the walls were plastered with adobe mud. The lining is three to four inches thick and baked by the fires which were subsequently built in them.

The hearths are the only ones of their kind so far found in connection with the Red-on-Buff culture and appear to have been a part of the early development of the culture, because in a later phase of the development the hearths were more

FIG. 14. SHALLOW HEARTHS OR FIREPLACES

*Upper*, AS FOUND; *lower*, AS EXCAVATED.

shallow and lacked the small pits in the bottom. Another sign of antiquity is the fact that but very little pottery was found in the hearths and most of it was undecorated.

The walls of the dwellings were built of stone two to four feet high and there was an opening or entrance on one side. The floor is four to six inches higher around the edge of the hearth than points at which the outer shelf begins, and the outer walls were built on this shelf. The shelf is two feet higher than the edge of the hearth and on the level of the general country. The houses were so-called pit houses and because of the hearth are given the name of "Circular Pit-Hearth Houses."

All the hearths contained ashes or charcoal and evidence of having contained numerous fires, but not necessarily large individual fires. There were also about eighteen inches of rocks on top of the hearth, in the interstices of which ashes and charcoal are found. It appears, from finding a hearth filled with rocks and no charcoal or ashes, that the kindling was laid, the rocks on top of this, and finally the fire was started. This heated the rocks, and these hot rocks were used to cook on and to heat the water for various purposes. This way there was a minimum of smoke. There are at least twenty or thirty more dwellings that are known but not excavated, and there were probably a great many more which have been destroyed by weathering. It is not possible to give a reasonable explanation of the holes in the bottom of the hearths, unless they were intended to catch the ashes for a number of fires. If they had been used as pottery kilns many fragments would have been found. An idea that occurs is that the bottoms may have had clan or religious significance. Of the ten hearths, so far found, only two hearth types or designs have recurred. The workmanship and general design lead to the belief that this type of hearth was in common use in the region and not original with the people of this camp, but a cultural trademark. At any rate, every dwelling could have sheltered a good-sized family, and the valley probably was reasonably populated at one time. The most likely purpose of the hearths was for cooking, roasting and heating purposes.

It is noticeable that a person, if stretched out with his feet at or near the edge of the hearth, finds his shoulder resting on the depression at the base of the shelf and his head on the shelf close to the house wall.

Many people could thus have occupied such a house, and with the floor covered with furs, it made a snug, safe shelter at night. The roof could have been made of inclined poles stuck in the ground outside of the stone wall and leaning on it, leaving a central opening at the top for the escape of smoke from the fire of the hearth. A covering of hides would not catch fire easily and would shed the rain.

It was not necessary to build a big fire to heat the stones. The tops of most of the hearths were found 1½ feet to 2 feet below wind-blown dirt which had been carried into the inside of the circular rock walls of the dwellings, filling the hearths as well, and the floors are well marked by fragments of burnt charcoal and occasional sherds of pottery. The floors are comparatively easy to find, because they are hard packed from use, while the wind-blown material is not packed.

The hearths were found by excavating in the center of the still remaining stone walls of the old dwellings and some of these rocks show signs of having been in a fire. No doubt the practise of using rocks of certain sizes on the fire was dictated by conditions and when a rock cracked due to heat and became too small it was thrown outside of the wall where it is now found.

Several stone-lined, circular, shallow

hearths, of which a photo of one is shown (Fig. 14) were found and one of these is in the center of a stone wall of a dwelling, from which it seems reasonable to suppose that both kinds of hearths were used. Were these smaller hearths the beginning of the larger hearths? These shallow open hearths must have been numerous, as ruins of them are common and many must have been destroyed because they were built so close to the surface. They give the impression of being summer hearths for cooking in milder weather, although the climate was perhaps semi-tropical at the time of occupation. The whole arrangement of the hearth and its surrounding walls was well calculated to keep the inside of the dwelling dry and warm in all seasons.

The skull, two views of which are shown (Fig. 15), when measured, gave a cephalic index of 84 which classifies it as a brachycephalic head or of the broad-headed type. It has been thought that the Red-on-Buff people were of the long-headed type, and they may have been, in which case the person to whom this skull belonged was an outsider, but this skull and another were found inside the large deep hearths and under conditions which lead to the belief that they were native Hohokam. More skulls must be found, however, to determine or decide this question. The fact that these people cremated their dead will make the question more difficult to ascertain.

## Designs of Pottery

Copies of various designs found on pottery are shown (Fig. 16) and are considered to be clever in design and good in execution. When it is remem-


FIG. 15. SKULL OF SKELETON FOUND IN NO. 7 TYPE HEARTH IS BRACHYCEPHALIC

Cephalic Index 84.

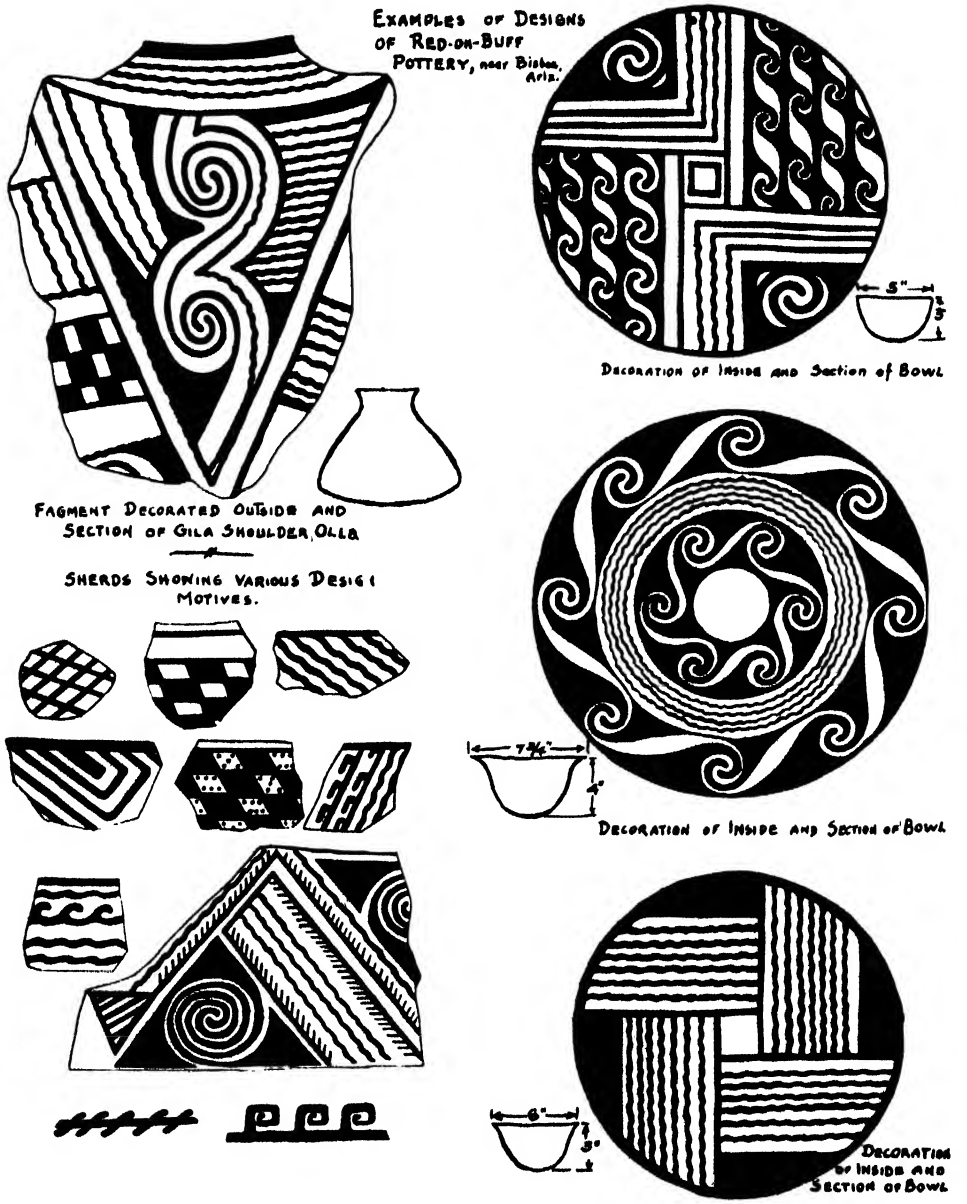


FIG. 16. EXAMPLES OF DESIGNS OF RED–ON–BUFF POTTERY, NEAR BISBEE, ARIZONA

bered that no potter's wheel or other means of laying out or putting on the work was known to these people, their craftsmanship is to be admired. For brushes they used the maguey or century plant, by cutting pieces lengthwise of the fiber to the width desired and fraying the ends. Numerous pieces of hematite were found in the camps, indicating that it was used for paint, and in order that a sharp continuous line may be drawn, it must have been necessary

to mix this finely ground material with some plant juice and water.

The background of the painted or decorated pottery which is buff owes its smoothness to slipping. Slipping is the art of applying a thin layer of fine clay on the rough surface of the green or burned pottery. In the latter case a second firing is necessary. The design and condition of the pottery come in the classification of the early sedentary period of this culture, say approximately 200 A. D., although this date may be pushed back or ahead, depending on evidence which may be found later.

### Irrigation

The culture has remarkable ditches to its credit in many localities and they are found to a limited but distinct degree in association with the campsites being discussed here. This phase of the campsites has been investigated only casually. They also built stone walls as terraces to hold the soil level and as a means of irrigating. A ten-acre field close to one of the campsites is studded here and there with irregularly placed heaps and cairns of rock which were piled up to permit farming and irrigation.

Although there is no running water, except during floods of rain, from the Mule Mountains into the valley at the present time, there probably was during the occupation of the campsites. Dry farming is a precarious means of existence under existing climatic conditions, and there are no springs, except in the mountains, so that for water these people must have had springs or running water closer to their sites than found at present.

### Defense

There are no encircling walls or means for defense in the campsites. Perhaps none were needed. The campsites are on no rise of ground but just out in the open. Evidently there were no wild animals that were especially feared by the community or from which it needed protection, and human enemies were either few or the Hohokam sufficiently schooled in open warfare in case of a surprise attack to be able to defend themselves without ramparts or defense walls.

At a distance of three to four miles from the sites, however, on top of Abbott's Peak, there were found six or seven circular stone walls with entrance openings well preserved which were evidently used as shelters by lookouts of the Hohokam. A splendid view of an unusually wide range is had from this peak and signal fires either day or night could easily inform the community of the approach of friend or enemy.

Abbott's Peak is crowned by a cliff of limestone which encircles the top in a manner which permits entrance to the top from only one place about fifty yards wide. At this place are found the remains of two or three successive parallel stone walls, which at one time were higher than at present and were put there for defensive purposes.

At several places at the base of or slightly below the cliff, metates, grinding stones, sherds of pottery and signs of dwellings were found, indicating that this peak was at one time occupied by a group of people either on the defensive or merely as lookouts or guards. There may be other look-out points, but they are not known. Much has still to be learned about this remarkable culture, but the information so far gathered in this small area, it is hoped, will add something to the sum total of what is already known and help toward unravelling the interesting but complicated and incomplete picture of the Hohokam.

# ANTHONY VAN LEEUWENHOEK AND HIS MICROSCOPES[1]

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WHAT the telescope is to the astronomer the microscope is to the biologist! Since the physical requirements of both these instruments are much the same, it is not surprising to find that the improvement and increased applications of one follow much the same path as do those of the other. Long before microscopes had been invented, however, simple lenses were in use. These lenses, doubtless employed for the inspection of small objects, were certainly known to the ancients. Pieces of rock crystal ground into biconvex forms were found by Layard in the ruins of Assyrian Nimrud, and Seneca tells us that hollow spheres of glass filled with water were used by the Romans to produce large images. The cutting of gems, an art which reached such high perfection in antiquity, must have been done under some kind of magnifier. In later times Roger Bacon (1214–1294) described a crystal lens as "useful to old men and to those whose sight was weakened, for by this means they will be able to see the letters sufficiently enlarged however small they may be." Spectacles were known to Chaucer (1340–1400), for he puts into the mouth of the wife of Bath the saying that poverty is a spectacle through which a man may see who are his real friends.

Yet notwithstanding these applications of lenses to the affairs of daily life, early science does not seem to have used such devices. The truly wonderful observation of Aristotle on the developing chick appear to have been made exclusively by his unaided eye, for he gives no intimation in his writings, so far as I am aware, that he ever used any artificial means as an aid to his vision. Pliny in his natural history has much to say about lentils but nothing about lenses.

The simple microscope, a biconvex glass mounted in a metal carrier, appears first to have come into general use at about the time of the Thirty-Years War (1618–1648). This instrument gained great popularity in that it was the means by which the movements of diminutive living creatures could be exhibited. Of these none was more frequently shown than the flea; hence the name of this device "vitrum pulicare" or, in common language, flea glass.

With the advent of the simple microscope there sprang up in Europe during the seventeenth century a flourishing school of workers, the early micrographers, who became enthusiastically engaged in the study of the minutiae of nature and who, by the use of the microscope, opened up a whole world of living forms never dreamed of by their predecessors. Chief among these early enthusiasts were Marcello Malpighi (1628–1694) of Italy, Robert Hooke (1635–1703) and Nehemiah Grew (1641–1712) of England, and last but not least Jan Swammerdam (1637–1680) and the subject of this essay, Anthony van Leeuwenhoek (1632–1723), both of Holland.

The lives of these two Dutchmen were almost exactly coincident with the golden age of the Netherlands. Following the struggles of William of Nassau the Dutch Republic gained its effective

[1] The author is under great obligation to Mr. Clifford Dobell for permission to quote freely from his recent volume, "Anthony van Leeuwenhoek and His Little Animals."

independence in 1609 and from that time onward it grew immensely in power and in riches. The middle of the seventeenth century may be taken as the culmination of this growth. At that time Amsterdam was the greatest trading center of Europe and the Dutch East India Company and the West India Company were the most powerful and successful commercial enterprises in the world. From a soil thus enormously enriched by commerce there arose an unprecedented artistic and intellectual efflorescence. Social life expanded, the arts flourished and science blossomed as never before. This was the time of the great Dutch painters Jan Vermeer, Jan Steen, Franz Hals and, above all, Rembrandt, At this time flourished the celebrated Dutch physicist, astronomer and mathematician, Christian Huygens, and the anatomists Franciscus Sylvius, Nicolaus Steno and especially Reinier de Graaf. Even the unassuming, excommunicated lens-grinder, Spinoza, brought to philosophy during this period a novel exaltation. Into this ferment of new life and ever-increasing activity were born the Dutch micrographers already named, Swammerdam and Leeuwenhoek. Although they were sons of one civilization their positions in life could hardly have been more in contrast.

Swammerdam, whose life has been completely sketched by Miall, was a native of Amsterdam and born into reasonable affluence. His father, a well-to-do apothecary, had established a private museum of natural history. Swammerdam the son was intended for the ministry, but he finally prevailed upon his family to let him study medicine. Meanwhile natural history became his passion and insects his special care. He attended the University of Leiden, where he made the acquaintance of Steno, de Graaf and Sylvius. He then traveled in France. On his return to Amsterdam he continued his anatomical and medical studies and perfected himself in methods of delicate dissection and injection under the simple microscope. In 1668 Cosmo, duke of Tuscany, visited Amsterdam, and when Swammerdam opened for him a fully grown caterpillar and showed him the wings, legs and other parts of the future butterfly in process of formation and packed away under the larval skin, Cosmo was so impressed that he offered Swammerdam a large sum of money for the latter's collections, provided that Swammerdam would come to Florence and settle there under the patronage of the duke. This offer Swammerdam finally declined, probably on religious grounds. In 1669, when he was thirty-two years old, he published his "General History of Insects." His health was far from robust, and disagreements with his father, who looked upon natural history as not a gainful occupation, led to difficulties. He was ambitious to complete further work on the insects and particularly on the day-flies and the hive-bee, and this he did despite a certain amount of parental opposition. His account of the day-flies was published in 1675. Five years later, in 1680, after serious illness and many financial worries, he died at the early age of forty-five. Thus Swammerdam's life reached its conclusion, the life of a man academically trained, reasonably traveled, cultured, dependent chiefly upon his family and short in years, in almost every respect the very opposite of that of his compatriot Leeuwenhoek.

Anthony van Leeuwenhoek was born at Delft in 1632. His life and doings have been most sympathetically and delightfully recorded in a recent memorial volume by Clifford Dobell, a scholar to whom all others are indebted for this labor of love. The parents of Leeuwenhoek were of good Dutch stock, his father a basket-maker of no personal or social distinction, his mother the

daughter of a well-to-do Delft brewer. Of their seven children Anthony was the fifth, born in the tenth year of their married life. The father died in 1638 when Anthony was five years old, and the mother, after a second marriage, lived till 1664. About the time of his mother's remarriage Anthony was sent to school at Warmond near Leiden. Apparently he never looked forward to a university career, for at the age of sixteen he went to Amsterdam, where he entered a linen-draper's shop to learn the business. While he was in Amsterdam it seems probable, according to Dobell, that he made the acquaintance of Swammerdam some five years his junior. After six years' apprenticeship in Amsterdam Leeuwenhoek returned to Delft, where he lived for the rest of his days. The Thirty Years War had ended, peace was reasonably assured for the time being, and Leeuwenhoek settled down into the quiet life of his native place.

Much of the quaintness and beauty of old Delft still remains. To the stranger of to-day, wandering along its quiet canals and shaded streets, it is easy to imagine scenes such as must have inspired the brush of an artist like Vermeer. In fact Vermeer's "View of Delft" and his "House on the Street," now both well-known classics in art, may be taken as evidence of how little the modern town has changed from that of the seventeenth century. It is a strange coincidence that on the death of Vermeer, which occurred at Delft in 1675, Leeuwenhoek was appointed official receiver to settle the greatly reduced estate of this noted artist. Life was even more circumscribed in those days than it is now.

In 1654, when Leeuwenhoek was twenty-two, he married. From this union were born five children, three sons and two daughters, only one of whom, Maria, lived beyond infancy. Leeuwenhoek's marriage year was notable in several respects. It was the year in which the great powder magazine in Delft exploded, killing hundreds of people and destroying many houses. This year likewise was the year in which peace was declared between England and Holland. It is not surprising then that at this time Leeuwenhoek should have bought in Delft a house and a shop and set himself up in business as a draper. According to bills now extant, he was buying and selling cloth, silk, ribbons, tape, buttons and the like. In 1666 his wife died, but in 1671 he married again, his second wife living till 1694. After her death his household was managed by his only surviving daughter, Maria, who is described by Dobell as devoted to her father. She cared for him in his old age when he was weak and infirm, and over his grave she raised a fitting memorial. She herself lived to be an aged woman, for she attained her eighty-ninth year. On her death her body was interred in her father's tomb.

Although Leeuwenhoek's business must have taken much of his time, he accepted in 1660 an appointment as Chamberlain of the Council-Chamber of the Worshipful Sheriffs of Delft. The duties implied in this appointment may be gathered from the wording by which it was ordered and which has been translated by Dobell as follows:

> Their Worships the Burgomasters and Magistrates of the Town of Delft have appointed and do hereby charge Antony Leeuwenhoek to look after the Chamber wherein the Chief Judge the Sheriffs and the Law Officers of this Town do assemble: to open and to shut the foresaid Chamber at both ordinary and extraordinary assemblies of the foresaid Gentlemen in such wise as shall be required and needful: item to show towards these Gentlemen all respect honour and reverence and diligently to perform and faithfully to execute all charges which may be laid upon him and to keep to himself whatever he may overhear in the Chamber: to clean the foresaid Chamber properly and to keep it neat and tidy: to lay the fire at such times as it may be required and at his

own convenience and carefully to preserve for his own profit what coals may remain unconsumed and see to it that no mischance befall thereby nor from the light of the candles: and he shall furthermore do all that is required of and that pertaineth to a good and trusty Chamberlain. For the which service the foresaid Antony Leeuwenhoek shall enjoy such wages benefits and emoluments as the foresaid lamented Jan Strick his predecessor in office did enjoy and shall enter into his duties upon the morning of the 24th of January 1660 and his wages shall be paid upon the same terms as those whereon the foresaid Jan Strick's were paid. Ordered by the Burgomasters in Council assembled this 26th day of March 1660 and signed by

J. Camerling. *Pensionary.*

In return for the performance of the duties as Chamberlain, Leeuwenhoek received 314 florins a year, a sum later increased to 400. Subsequently he added to this position that of "Generaalwijkmeester" or alderman, for which he received an additional annual stipend of 50 florins. Both these appointments, according to Dobell, were probably sinecures and their duties were performed by proxy. In 1669 Leeuwenhoek was admitted as a surveyor within the jurisdiction of the Court of Holland, a step which he could not have taken, had he not had considerable knowledge of applied mathematics. He was now in his thirty-seventh year, a well-established and respected tradesman in Delft.

Thus far Leeuwenhoek had had no outward connections with the learned world, but in 1673 he began those associations with the Royal Society of London that were to extend throughout half a century and were to be terminated only by his death. How these associations arose has been fully narrated by Dobell. The Royal Society of London, founded about 1660 for the promotion of natural knowledge, was desirous of getting into communication with all those who sympathized with its aims. To this end its first secretary, Henry Oldenburg, carried on a voluminous correspondence with savants the world over, and among these was Reinier de Graaf, the friend and townsman of Leeuwenhoek. Through Oldenburg, de Graaf learned of the new and remarkable microscope made by Eustachio Divini in Italy, by which the inventor had been able to discover "an animal lesser than any of those seen hitherto." That Holland should not be outdone by Italy de Graaf addressed the following words to Oldenburg as translated by Dobell:

That it may be the more evident to you that the humanities and science are not yet banished from among us by the clash of arms, I am writing to tell you that a certain most ingenious person here, named Leewenhoeck, has devised microscopes which far surpass those which we have hitherto seen, manufactured by Eustachio Divini and others. The enclosed letter from him, wherein he describes certain things which he has observed more accurately than previous authors, will afford you a sample of his work: and if it please you, and you would test the skill of this most diligent man and give him encouragement, then pray send him a letter containing your suggestions, and proposing to him more difficult problems of the same kind.

De Graaf's letter was accompanied by a sample of Leeuwenhoek's work, which included observations on mould, the sting, mouth-parts and eye of the bee, and the louse. These observations so interested the members of the Royal Society that its secretary was instructed to communicate with Leeuwenhoek, who replied as follows:

I have oft-times been besought, by divers gentlemen, to set down on paper what I have beheld through my newly invented *Microscopia:* but I have generally declined; first, because I have no style, or pen, wherewith to express my thoughts properly; secondly, because I have not been brought up to languages or arts, but only to business; and in the third place, because I do not gladly suffer contradiction or censure from others. This resolve of mine, however, I have now set aside, at the intreaty of Dr. Rag. de Graaf; and I gave him a memoir on what I have noticed about mould, the sting and sundry little limbs of the bee, and also about the sting of the louse. This memoir he (Mr. de Graaf) conveyed to you; whereupon you sent me back

an answer, from which I see that my observations did not displease the Royal Society, and that the Fellows desired to see figures of the sting and the little limbs of the bee, whereof I made mention. As I can't draw, I have got them drawn for me, but the proportions have not come out as well as I had hoped to see 'em; and each figure that I send you herewith was seen and drawn through a different magnifying-glass. I beg you, therefore, and those Gentlemen to whose notice these may come, please to bear in mind that my observations and thoughts are the outcome of my own unaided impulse and curiosity alone; for, besides myself, in our town there be no philosophers who practise this art; so pray take not amiss my poor pen, and the liberty I here take in setting down my random notions.

According to Dobell, a week before Leeuwenhoek sent to the Royal Society the letter just quoted Constantijn Huygens, diplomat and father of the physicist, wrote as follows to Hooke:

Our honest citizen, Mr. Leewenhoeck—or Leawenhook, according to your orthographie—having desired me to peruse what he hath set down of his observations about the sting of a bee, at the requisition of Mr. Oldenburg, and by order, as I suppose, of your noble Royal Society, I could not forbear by this occasion to give you this character of the man, that he is a person unlearned both in sciences and languages, but of his own nature exceedingly curious and industrious, as you shall perceive not onely by what he giveth you about the bee, but also by his cleere observations about the wonderfull and transparent tubuli appearing in all kind of wood. . . . His way for this is to make a very small incision in the edge of a box, and then tearing of it a little slice or film, as I think you call it, the thinner the better, and getting it upon the neddle of his little microscope—a machinula of his owne contriving and workmanship—brass. . . . I trust you will not be unpleased with the confirmation of so diligent a searcher as this man is, though allways modestly submitting his experiences and conceits about them to the censure and correction of the learned. . . .

Thus through these several agencies was Leeuwenhoek introduced to the Royal Society and thus began that remarkable series of communications in which he contributed to the society a fund of knowledge made possible by the use of his microscopes.

It seems quite clear that for some years previous to 1673, when Leeuwenhoek became known to the Royal Society, he had been grinding lenses and making microscopes, but when and how these activities began no one appears to know. Suffice it to say that in the year mentioned he had gained no small degree of skill in this practise and that this skill and its results were recognized by such men as de Graaf and the elder Huygens.

The instruments commonly designated as Leeuwenhoek's microscopes are fortunately fairly well known to us. At his death, as can be ascertained from the auction list of certain of his effects, it is known that he left 247 completely finished microscopes and 172 mounted lenses, or 419 pieces in all. The great majority of these have disappeared, including the "little cabinet, lacquered black and gilded that comprehendeth within five little drawers wherein lie inclosed 13 long and square little tin cases which I have covered over with black leather, and in each of these little cases lie two ground magnifying glasses making 26 in all everyone of them ground by myself and mounted in silver." This cabinet was bequeathed by Leeuwenhoek to the Royal Society, safely received by it, not infrequently inspected by its Fellows, but finally duly and totally lost. In fact Dobell reports that of the 419 lenses known to exist at the time of Leeuwenhoek's death, at present only eight can be accounted for with certainty and all these are held on the continent, England and America possessing none. These eight, however, with the descriptions of others, give us ample ground for reconstructing the instrument.

This consisted of two parallel plates of metal, brass, silver or even gold, held together by rivets and carrying between them in their upper central part one of the precious lenses held firmly opposite holes in the plates, so that the observer could put his eye next the united plates

and peep through the aperture with its contained lens at any object held on the opposite side. Such object was not supported by the hand but by a metal point which terminated a rod itself attached to the lower part of the plate in such a way that it could be moved by threaded screws into appropriate position for inspection and clear focus. The object to be examined was either mounted on the metal point by being stuck there with glue or it was placed on a bit of thin glass or mica or between two pieces of such material or in a capillary tube. These partial mounts were attached of course to the metal point. Thus a great variety of substances could be brought under inspection. Leeuwenhoek's method of demonstration was such that he usually made a microscope for each object and having set up the whole, he retained it in that form for inspection instead of changing the object under the glass, as was later commonly practised.

It will be seen at once from this brief description that Leeuwenhoek's so-called microscopes were little more than simple lenses and that they bore no resemblance whatever to the compound microscope of even his day. This instrument, in which one lens or lens-system magnifies the image formed by another, was indeed known at his time, but it was so imperfectly developed that even the relatively crude magnifier made by Leeuwenhoek far outran it in efficiency. The great success that Leeuwenhoek's microscopes attained turned, it appears, on the marvelous skill with which he ground his lenses. In early times, when many of these lenses were available, they were carefully examined by expert opticians and were pronounced by them as unusually free from optical defects, notwithstanding that they were of relatively high power. His better lenses are known to have magnified 270 diameters, and it is possible that some of his best products, of which he seems to have been very choice, reached as much as 300 diameters.

A perusal of Leeuwenhoek's letters and the comments of his contemporaries show that he guarded his best work with a certain jealousy and secrecy. He often implies in the accounts of his observations that he could see what many others could not. He intimates further that he possessed methods of manipulation which placed him personally at an advantage over others and which he was loath to impart to them. This professional secrecy, if such it was, formed a part of his psychology and Dobell has rightly called attention to it. What it was all about is not easy to surmise. It is, however, certain that he observed and figured many bodies that it would be very difficult for even an unusually skilful observer to make out with the equipment ordinarily attributed to Leeuwenhoek. That he had certain remarkable lenses at his disposal that never were allowed to come to light is very unlikely. His secret, if he had one, was probably in his method of manipulation. Dobell has suggested that he may have used some form of indirect illumination, a step entirely possible with his apparatus. When it is recalled how greatly this method would have improved the possibilities of viewing very minute objects, such as bacteria and the like, it seems more than probable that Dobell is correct in his surmise and that this was the step in Leeuwenhoek's manipulation that set him so far in advance of his competitors and that he was so loath to reveal. In support of this suggestion Dobell quotes Leeuwenhoek, who in reply to a criticism remarks, "but I can demonstrate to myself the globules (corpuscles) in the blood as sharp and clean as one can distinguish with one's eyes, without any help of glasses, sandgrains that one might bestrew upon a piece of black taffety silk." Precisely this comparison would hardly have occurred to Leeuwenhoek had he not been accustomed to view microscopic objects on a dark background, such as is produced by in-

direct illumination. His vision was known to have been remarkably acute, but added to this there must have been some other turn in manipulation which gave him supremacy, and indirect illumination may have been that turn.

Equipped with unusual apparatus and technique, filled with a burning curiosity about all natural objects, and with fifty years of life ahead, Leeuwenhoek at the age of forty-one began a scientific career of remarkable discovery and accomplishment. His physical needs were met by the income from his shop and his town appointments. His time was largely his own and he was thus free to follow the passion of his later life.

During these fifty years Leeuwenhoek spread his scientific discoveries by writing letters mostly to the Royal Society, and many of these were published in its *Transactions*. In 1680 he was elected a fellow of the society, an honor which gave him great satisfaction. As a result of his work he became more and more widely known and was visited by celebrities as well as by others from all over the learned world. As Dobell writes, "kings and princes, philosophers and physicians and men of science, statesmen and clergymen and even common men went to see him and to look through his wonderful glasses." The visit of Peter the Great of Russia has been recorded with much detail. This monarch was so interested in what Leeuwenhoek had to show him that he detained Leeuwenhoek no less than two hours and on taking his leave shook Leeuwenhoek by the hand and assured the micrographer of his special gratitude. But Leeuwenhoek was not to be lionized. His heart was in his work and visitors took his time. Finally many were denied admittance, but he always endeavored to make himself accessible to those who came from the Royal Society. In this respect the following comment concerning visitors from Sir Hans Sloane, then secretary of the society, is not without interest. "Mr. Hans Sloane recommended Mr. Stuart to me, in his letter, as a curious Gentleman who has travelled through many countries; and the same Gentleman had two other Scottish gentlemen in his company, all of whom I gladly received, and so will I do all those who have an introduction from Mr. Sloane." Mr. James Petiver, however, was less fortunate. After an unsuccessful attempt to visit the micrographer in 1711, Petiver received from Leeuwenhoek a letter, from which the following significant extract is taken:

> I have received your Letter of the 2nd of August anno 1711, wherein you are displeased at not being welcomed at my house. I beg you please not take it ill, seeing that we send off everyone who tries to visit me unless they have some sort of introduction. . . . If you had kept by you the letter from Mr. Hans Sloane, you would not have missed a friendly entertainment at my house. And you were sent away especially because you were not known, and because some 8 or 10 days earlier no less than 26 people came to see me within four days, all of them with introductions (except a Duke and a Count with their Tutor): which made me so tired, that I broke out in a sweat all over.

Thus was poor Leeuwenhoek in his seventy-ninth year pestered by an importunate public.

Yet notwithstanding interruptions work went forward. In 1717 Leeuwenhoek really thought his end was near, and he wrote what he believed to be his last letter to the Royal Society, concluding with

> Methinks these will be the last observations I shall be able to send to you honourable Gentleman; because my hands grow weak, and suffer from a little shakiness, which is due to my advanced years, a good 85 having passed by me. And so I send you with this my deep thankfulness, because in the year 1679 you were so kind as to elect me, quite beyond my competence, a Fellow of the most worthy College of the Royal Society; and to send me a Diploma, together with two letters from the Secretaries of the Society, which likewise made known to me my election, by all the votes of the Fellows, then gathered together at a very full meeting.

I thank you also for the *Philosophical Transactions*, which Your Excellencies have been so good as to send me from time to time.

For all these honours and gifts aforesaid, I herewith convey to you my gratitude once more.

Yet after this letter Leeuwenhoek lived nearly six more years and sent to the society in that time no fewer than eighteen more epistles. But the end finally did come on the twenty-sixth of August, 1723. The Reverend Mr. Peter Gribius notified the fellows of the Royal Society of Leeuwenhoek's death, and his daughter, Maria, arranged his funeral and carried out his last wishes. Leeuwenhoek was buried in the Old Church of Delft on Sunday the thirty-first of August, 1723, "with 16 pallbearers and with coaches and tollings of the bell at 3 intervals." In 1739 his daughter Maria erected a monument to his memory in another part of the church where he now lies. Here she too was later buried. Thus concluded the life of a man who without a vestige of university training and utterly devoid of academic associations contributed to the scientific advance of his day as did scarcely another.

What these advances were may be mentioned only briefly. Leeuwenhoek confirmed and extended Malpighi's observation that the arteries connected with the veins by a system of very fine vessels, the capillaries. These Leeuwenhoek demonstrated in the tail of the tadpole and the eel, in the web of the frog's foot, and in the membrane of the bat's wing. He pointed out significant differences in the blood corpuscles of various animals. He was first to note the cross-striation of muscle fiber and the fibrous structure of the lens of the eye. Following the initial observation of Hamm, he began a study of spermatozoa, of which he believed he could distinguish two kinds, one giving rise to male offspring and the other to female, an anticipation of the modern doctrine but on wholly erroneous grounds. He studied cilia in the edible mussel and the embryos of the fresh-water clam and was a vigorous opponent of spontaneous generation. He studied the life history of the plant-louse and discovered viviparity. He watched fleas hatch from their eggs and showed that the so-called eggs of ants were their pupae. He plunged into the question of the nature of cochineal, and finally declared in favor of the view that it is a dried insect. He showed that the compound eye as such occurred in crustaceans as well as in insects. He studied the structure and breeding habits of spiders and watched them hatch from their eggs. He discovered rotifers and showed that they could undergo desiccation without consequent death. In the dried state he believed them carried from place to place as dust in the wind. He first described the fresh-water hydra, volvox, and so many of the flagellate and ciliate infusorians that he is usually regarded as the father of protozoology. He described the yeast plant and was the first to observe bacteria. These he studied and described from his own mouth, where he found them in and about his teeth. Such materials and a host of others claimed Leeuwenhoek's ingenious attention and afforded subject-matter for his eager, inquiring mind. Neither trained nor informed in speculative science he at times laid himself open to violent attacks from his opponents but, skilled beyond all others in direct observation, he amassed and handed down a body of knowledge prodigious in amount and unbelievable in importance. A simple, earnest, inquiring soul, in outward form an unassuming tradesman, in inward truth a burning flame of purest science.

# A CENTURY OF PROGRESS IN THE CHEMISTRY OF NUTRITION[1]

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THE occasion for which this paper is invited falls so near the completion of the first third of the twentieth century that we may conveniently divide our brief sketch of the progress of the chemistry of nutrition during the past hundred years into three periods of a third of a century each.

## I

At the opening of the middle third of the nineteenth century, chemistry had accumulated a number of discoveries which we now recognize as fundamental to the science of nutrition; but little of what we could now consider an actual science of nutrition yet existed.

Lavoisier had shown the fundamental resemblance of oxidation of organic foodstuffs in the body with their burning in the air; Wohler had shown the possibility of the laboratory synthesis of substances previously known only as products of life; and several investigators had demonstrated the existence of organic catalysts of the sort that we now call enzymes; but these great discoveries had not yet been made effective through the building of the chemistry of nutrition as a clearly conceived and coordinated science.

This, Liebig was just about beginning to do a century ago. His first book on the significance of chemistry for agriculture and physiology appeared in 1840 and his classical treatise on animal chemistry followed only two years later. His principle, frequently called the "Law of the Minimum," was enunciated in 1843 and has ever since had an enormous influence upon the methods and interpretation of research in the nutrition both of plants and of animals.

Voit carried on the development of the chemistry of nutrition which Liebig had so effectively launched; for Voit, like his distinguished student, our dear friend the late Dr. Lusk, while bearing the title of professor of physiology, worked essentially in the chemistry of nutrition.

At the end of this middle third of the nineteenth century, the concept of chemistry as functioning in the nutritional processes in plant and animal life—in both the formation and the utilization of our foodstuffs—was being made effective for animal physiology by Voit at Munich, while in this country work much like Liebig's own, in its comprehensive grasp of the interrelated problems of the farm crop, the domesticated animal and man, was being done by Samuel W. Johnson, under whom Atwater was a graduate student at Yale in the late sixties, and under whom also Osborne began and developed his far-reaching researches upon the proteins.

Perhaps this is the point at which to explain that as time would not in any case permit the mention here of more than a fraction of those to whom honorable mention is due, no living person will be named in this review.

## II

During the last third of the nineteenth century, the work of Pasteur was becoming fully effective.

[1] A paper prepared upon invitation of the American Chemical Society for its meeting at Chicago, September, 1933.

While the name of Pasteur is more intimately identified with fermentation and infection than with nutrition in the ordinary sense, yet Pasteur, in addition to being the chemist who became the father of modern bacteriology, was also the one who, perhaps more than any other, made clear and convincing the far-reaching principle that life processes are amenable to successful investigation by chemical methods and from the chemical point of view. In fact it has been said that the reason Pasteur progressed more rapidly than other bacteriologists in the study of disease was because he adhered to the chemical viewpoint and concentrated his attention not so much upon the morphology of the microorganisms as upon their relation to the substances which nourish them and the substances which they in turn produce.

Under such influences, then, as those of Pasteur, of Liebig and Voit, of Johnson and Atwater and Osborne, the latter part of the nineteenth century was both laying the scientific foundations for the science of nutrition and preparing the ground for its acceptance and for its effective service to human welfare.

Before the nineteenth century was over, the work of Osborne and others had added to chemistry a substantial list of proteins known as purified individual substances and ready to be studied with reference to the nutritional significance not only of their general chemical nature but also of their differences in chemical structure, particularly in their amino acid make-up.

Also, largely through the work of Frankland in England, of Thompson and Stohman in Germany and of Berthelot in France, the heats of combustion of the chief organic nutrients and of many of their metabolites had been determined quantitatively; Rubner had successfully studied the energy exchange of the body as a whole by direct experiments upon dogs, and Atwater by analogous and even more accurate experimentation upon men, so that the study and teaching of the energy relations of nutrition were beginning to take on the character of the exact sciences.

Many quantitative experiments had also been recorded in connection with the study of the protein factor in nutrition; and Osborne had published his finding (the significance of which was not fully appreciated until much later) of the protein nature of malt amylase—an enzyme typical of one group of the catalysts through whose action the energy value of the organic foods is brought with sufficient promptness into the nutritional service of the body.

Forster and a few others had given some attention to the rôle of the mineral elements in nutrition but appreciation of the importance of these was inhibited by preconceptions mistakenly carried over, without due discrimination, from the study of the nitrogen metabolism.

Eijkman had recorded what we now know to be good experimental evidence of the existence of a nutritional deficiency disease; but had, as a committee of the British Medical Research Council afterward phrased it, presented his findings "with so strong a pharmacological bias" as to obscure their nutritional significance, so that his work did not actually become a contribution to the chemistry of nutrition until it could be re-viewed in the light of the more chemical work which followed after the turn of the century.

From the American view-point, it is of interest to note that before the end of the nineties there was a strong center of advanced teaching and research in physiological chemistry at Yale, food chemistry was well developed in several of our colleges and universities, every state had in its Agricultural Experiment Station a center of research in agricultural chemistry which in many cases was

beginning to include consideration of the nutrition both of plants and of farm animals, and the United States Department of Agriculture was conducting research in the nutrition of man under the direction of Professor Atwater.

III

Gratefully acknowledging that we have reaped where our predecessors of the nineteenth century had sown, we may well emphasize the striking extent to which the present-day chemistry of nutrition has developed during our own first third of the twentieth century. The development of this newer knowledge of nutrition places upon the present generation of chemists a much heavier responsibility than has been borne by the chemists of the past, and opens to them a correspondingly greater opportunity for scientific scholarship and for service to human welfare.

Both in the interest of clearness and on logical and chronological grounds, we may speak of six steps in this line of scientific development, or (to change the figure) six "pillar concepts" on and around which our scientific structure is being built:

(1) The quantitative studies of the energy relations, now recognized as fundamental to the development of nutrition as an exact science; and now so far successful that one may speak with confidence and with precision of the chief substances whose oxidation in the body yields energy for its nutritional functions, the amounts of energy which these substances thus yield and the approximate amounts of energy which the body normally transforms at different ages and under different conditions. Current research in this field is constantly adding precision to our knowledge of the energy needs of normal nutrition and, in the hands of many workers, is showing more definitely what departures from the normal are to be expected in the different types and degrees of disease. The world-wide study of racial factors and climatic influences is also a far-reaching development in this field of research.

A connecting link with the second aspect of our subject is encountered when we ask how the chemical reactions upon which the energy exchanges depend are made to run fast enough in the body to meet its nutritional needs. A few words from the more familiar view-point of the proteins in nutrition must, however, intervene.

(2) Quickly following upon the markedly successful quantitative developments in the studies of energy relations, which were the outstanding news in nutrition at the turn of the century, came a truly epoch-making period of experimental enlightenment in the protein chemistry of nutrition. The proteins which Osborne, in this country, Fischer, in Germany, and others, had so systematically studied as chemical entities were now fed individually under closely controlled conditions to well-standardized laboratory animals and the chemical structures and nutritional relationships were correlated in terms of the qualitative and quantitative differences of the individual amino acids which the food proteins supply.

And here a most interesting and important two-fold development has occurred. On the one hand it has been found that some of these amino acids are more or less interchangeable while some are individually quite indispensable, each having evidently its own unique function or functions in nutrition. And on the other hand it has been found that several of the catalysts directly or indirectly essential to the energy metabolism, for instance, the glutathione which appears directly to catalyze the oxidation process, thyroxine and adrenaline which in some way expedite the process, insulin which facilitates some intermedi-

ate or preparatory reaction, and the typical hydrolytic enzymes which bring the organic foodstuffs into forms upon which these other catalysts can act—all these now appear to be derivatives of amino acids such as result from the digestion of food proteins.

Such discoveries point the way to still further scientific advances and they have an enormous practical value in showing how the proteins (or protein mixtures) of different articles of food can supplement each other with most efficiency and economy both in human nutrition and in the feeding of farm animals.

Tempting as it is to dwell longer here, we must turn now to the third of the six steps or aspects in which we are seeking to indicate (how be it all too meagerly!) the recent development of our subject.

(3) Gradually, during the past thirty years, in part following upon the twentieth century reform in our ideas of the protein factor in nutrition and in part independently, there has come an awakening to the importance of several of the mineral elements. The fact that several of these elements are regularly found in the body, and the effects which had been observed in a few rather primitive experiments with diets in which they had been very drastically reduced, had been generally accepted as indicating that they play some part in nutrition, but the amounts needed were usually underestimated and it was generally assumed that chance intakes would practically always be adequate. The investigations of the past thirty years have dispelled this fallacy with regard to one mineral element after another and shown that it is both scientifically significant and practically profitable to give these elements the same careful attention that we give to protein. The practical importance of the mineral elements as factors in food values is even greater in human nutrition than in animal feeding, because of the tendency to over-refine human foods and to divert to the feeding of animals those "coarser" parts which are usually richer in the mineral elements.

Recent advances in our knowledge and appreciation of the rôle of the mineral elements in nutrition has given us the key, certainly to the prevention of much of the malnutrition hitherto so prevalent, and we hope also to a constructive advance in our standards of positive health.

(4) Almost simultaneously with this gradually dawning realization of the importance of the mineral elements, and doubtless obscuring it in the view of many, there has come a dramatic series of discoveries regarding the existence in food and the significance in nutrition of a whole group of substances, not particularly related in their chemical natures or nutritional functions, but which are commonly called the vitamins.

Scientifically the vitamins should not go under a group name for they are not a sufficiently similar or related group of substances. The more we learn about the vitamins the less alike do they appear. That they have been so grouped is the accidental result of their existence having been discovered and their nutritional importance established in too rapid a succession for the actual physical isolation and complete chemical identification of the substances to keep pace, even though many able chemists have been working actively upon the pure chemistry of these compounds.

When this situation is fully grasped it constitutes in itself a most impressive demonstration of the rapidity with which so many fundamentally important discoveries have been made in this field in the past few years.

What from habit is still called the vitamin concept is in reality a whole group of concepts, each unique.

Even so, there are still other concepts which we should also consider.

(5) Another important aspect of the recent progress in the chemistry of nutrition is found in the interrelationships between the different nutritional factors. Thus, as already noted, the energy metabolism depends upon catalysts containing or derived from the proteins or their amino acids. Or, again, in hemoglobin, the body makes itself a substance which is outstanding both as a body protein and as an iron compound and which plays a leading rôle both in transporting oxygen for the energy metabolism and in maintaining the acid-base balance.

Still again, research upon the interrelationships of calcium, phosphorus, and vitamins A, C and D has added greatly to our understanding of the chemistry of the body and has shown the way to the conquest of rickets and scurvy—and, we hope, to the building of better teeth.

We also have reason to hope that the chemistry of nutrition is well on the way toward a solution of the pellagra problem through the working out of the nutritional interrelations between vitamin G and whatever other factors are involved.

If something of the order of thirty-odd chemical entities (elements or compounds as the individual case may be) must be nutritionally supplied to the body from without,[2] besides all the substances that it makes within itself, application of the algebra of combinations and permutations will soon show that a human life-time would not be sufficient for the consideration of all possible interrelations. Plainly this promises to be almost too fertile a field, a region in which the investigator must guard against losing himself in a veritable jungle growth of interrelationships.

As a compass or polar star for our guidance, however, we have what we are here calling the sixth step or aspect in our present-day concept of the chemistry of nutrition.

(6) This is the principle that in the chemistry of nutrition our ultimate concern is essentially the nutritional reactions of the living body as a whole. For the living body is a coordinated whole: and such a whole is something more than a mere summation of its parts. However interesting and important it may be to follow individual chemical substances into individual bodily organs and to trace detailed interrelations among the many factors essentially involved in nutrition—and it is thus that much of our knowledge has been, and must be, won—we have recently learned the importance of remembering also that, somewhat as in practical affairs, the proof of the pudding is in the eating, so in the most far-reaching ambitions of research in nutrition, the court of last resort is the experiment, or closely-reasoned series of experiments, conducted with all possible exactness and the most careful laboratory control, upon the whole animal, often throughout its whole life-cycle, and sometimes even through successive generations.

The demands of brevity confine us here to a mere hint at the far-reaching

[2] At the time of writing (September, 1933) the views of different chemists as to what the body needs nutritionally from without would range from twenty-five items upward, as indicated by the following summary: (1) At least fifteen of the chemical elements in the strict chemical significance of that term—carbon, hydrogen, oxygen, nitrogen, calcium, phosphorus, potassium, sulfur, sodium, chlorine, magnesium, iron, iodine, copper, manganese, and perhaps others; (2) from four to fourteen of the amino acids furnished by the proteins of the food; (3) probably at least a little of some unsaturated fatty acid; (4) certainly at least five vitamins. That one must still speak so tentatively upon such a fundamental question as, "What does the body nutritionally need from without?" is a striking illustration of the rich field which here awaits further research notwithstanding the great advances which have been made during the past three decades.

significance and prospects of such research. Even so, it may be pointed out that the discovery of the vitamins is merely a beginning of this new chapter in the chemistry of nutrition; for research has promptly pressed on from the qualitative finding of the existence of previously unknown factors to the quantitative study of their optimal intakes in nutrition. And just as the discovery of the vitamins shows how to avoid deficiency diseases, so the more comprehensive and quantitative type of research covering whole life-cycles and sometimes successive generations of experimental animals is showing the way to advances in positive health. Thus it has been found that, starting with conditions already normal, the quality of the life process may be improved and the average length of healthy life may be significantly extended by so adjusting the relative proportions of every-day foods as to enrich the dietary in certain of its chemical factors. Not only is life made longer, it is also made richer and more efficient throughout.

There are indications that too greatly "forced" growth may be unfavorable to the longevity of the individual; but within the limits of the normal there is apparently a wide zone of possible improvement in the hitherto accepted averages of nutritional accomplishment. Growth and development can be helped and old age can be deferred in the same individuals and by the same chemical improvements in the nutritional intake. Granted that there are limits beyond which growth and longevity can not both be pushed, there is still a rich field of scientific interest and of service to human welfare in the extension of the period of the prime of life by the further development of this quantitative aspect of the chemistry of nutrition.

We are not primarily concerned with the question whether such chemical improvement in the life process through nutrition will materially change the outward physical aspects of the species or the general nature of its chemistry: both these are probably pretty well stabilized by now and individual differences in physical characteristics are probably chiefly determined by the arrangement of the genes in the chromosomes before birth. What we are learning through research in the chemistry of nutrition is, rather, what things and in what relations to feed into the body in order that it may be helped to maintain a more constantly optimal chemical environment within, and we have reason to anticipate that such chemical improvement of the internal environment may be favorable to further human progress.

At any rate, from now on, nutrition can furnish to food economics a more certain and serviceable guidance than has ever before been available. And with the means of education which now exist we may feel confident that, whether through a planned economy, or through the effect of enlightened consumer demand, or both, this newer knowledge of nutrition will continue to become more and more effective.

To increase the proportion of people who, like many that we have already known, are able to render a longer and more efficient service than the average, and whose services, as Eliot pointed out, are of added value in their more mature years because then the community recognizes them as both experienced and disinterested—this will mean much to civilization as well as to the individuals who will receive this longer lease of healthier life through the advances which are just now being made in our knowledge of the chemistry of nutrition.

# SCIENCE AND NUMEROLOGY

By Professor JOSEPH JASTROW
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No one knows who invented the term "Numerology" or when it was first used. The absurd doctrine which goes by that name is in its application an entirely modern device, prompted apparently by the popular success of astrology as a profession, or more accurately, a racket. Some ingenious promoter realized that there was money in the proposition that one is born not under a star but under a number. The original idea in modern numerology is not the technique of calculation—which is an old one—but the notion that the result, which is expressed as a digit, carries with it an entire array of character-traits.

If to the letters in John Doe's name are assigned the numerical value of their position in the alphabet, counting from 1 to 9, and beginning again, thus:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| J | O | H | N | | D | O | E |
| 1 | 6 | 8 | 5 | | 4 | 6 | 5 |

and the numbers added, namely 35, and the 9's thrown out, the result is an 8; and John Doe is an "8." Being an "8," he has a lot of characteristics such as wishing to manage big affairs, the power to struggle against opposition and in general is a corner-stone in the community. The same hocus-pocus is applied to the date of birth, and endless frills increasingly absurd. This and a mass of similar rubbish makes up the "Numerology" that sells.

Professor Bell had the happy idea of rescuing the word, which is a convenient one, and making it include all the varieties of doctrine, from Pythagoras onward, that ascribe mystic meaning and peculiar power to numbers. From now on that should be the meaning of Numerology, and not the absurd system of reading character and fortune in the arbitrary number-equivalents of names, which represents about the crudest superstition and the lowest cerebration that flourishes in these supposedly enlightened days.

Professor Bell is a distinguished mathematician in the California Institute of Technology. He has issued a book bearing the title "Numerology,"[1] which introduces a distinction that will serve as a permanent classification, and may cause surprise at first, to be followed by complete acceptance of the happy idea. His dictum reads that the (or one) opposite of science is numerology. For false as may be the doctrine throughout, what is now a debased and profane distortion was once a sacred doctrine. This survey of the origin and career of the type of thinking which numerology represents is one of the many merits of Professor Bell's engaging contribution.

Although everybody uses the word, it has not (until recently) been admitted to the standard dictionaries, because it is regarded as a coined word, associated with a very shady system. The libraries have been similarly orthodox; one must look for books on this subject under the title "Symbolism of Numbers."

The father of numerology in the catholic sense, is Pythagoras. Professor Bell, speaking as a mathematician, sets forth:

> It makes not one particle of difference to-day whether a particular mathematical theory of the universe is fantastic nonsense, provided only the theory is of some use for a week or more in guiding scientific work. Because some theory makes correct predictions in three or three hundred instances is no evidence that it is more than a fictitious scaffolding of imaginary and unnecessary lumber. In so far as anyone believes the contrary, to that extent is he a

[1] Eric Temple Bell, "Numerology," Williams and Wilkins Company, Baltimore, 1933.

**numerologist in the traditional sense of the Pythagoreans. . . .**

**Pythagoras was a pioneer . . . first in each of three fields which we still cultivate, philosophy, science and numerology. A great philosopher, a great scientist, he was also a numerologist, and by the last he is most remembered. . . . Had Pythagoras been invited to define numerology he might have described it as the love of numbers for their own sake.**

Pythagoreanism goes farther than this in that it makes the universe an incorporation of the simple relations of numbers; thus does cosmos emerge from chaos. And Pythagoras had a remarkable fact to go upon: namely, the discovery that the relations of the three simple musical intervals, the octave, the fifth and the third, can be expressed by the relations of 1 to 2, 2 to 3 and 3 to 4. "The fact that a beautifully simple relation exists between *small whole numbers* and *musical sounds* astonished and mystified the Pythagoreans, as well it might have done. Few human beings find anything so beautiful. Numerology was born the hour Pythagoras discovered the law of musical intervals. But this "brilliant discovery tricked him into universal numerology." Hence the "harmony of the spheres" and the Pythagorean dictum that all things are fittingly ordered according to the nature of numbers; number is the eternal essence; God is number; number is God. With that the mischief was done; twenty-five centuries later we have the plague of "numerology."

With this start, numbers were assigned moral qualities and forms also. *1* was a masculine number representing unity, and *2* a feminine number, representing discord. The circle was the "perfect" figure; for centuries the orbits of the planets were coerced into more and more complex systems of orbs and cycles until eventually Keppler discarded all this prepossession and found the true orbit in an ellipse. Numbers were perfect and imperfect, odd and even, and assumed qualities similar to the distinction of right and left, which makes sinister—left—equivalent to ill-omened. Plato, continuing the same tradition and in far more mystical fashion, summed it up by saying that God geometrizes. All this is "Numerology," a generic category of pseudo-science.

Numerology developed a numerous progeny, each more bizarre than the others. The system that reached the greatest vogue was of Jewish origin in early Christian days and received the name of the Kaballa. Its technical name was Gematria. The number-scheme by which John Doe finds his numerically equivalent number is a weak form in scriptural texts of Gematria. The Kaballists found mystic meaning by adding up the number-equivalents of names. Gematria is a word admitted to the dictionaries and libraries. To indicate that it still flourishes, I mention a work projected in seven volumes, three of which have appeared since 1932, entirely devoted to numerological texts, from which the truth of the Scriptures and the fate of the great war may be rigidly deduced. So recent and so continuous is numerology. The number of persons who have gone mad on numbers is numberless.

Numerology received its largest theological vogue from the number of the beast in St. John, "666." This text gave rise to what Professor Bell calls "beasting," attributing this malign number to one's favorite enemy. The numerologists of the Reformation fastened it upon Leo Xth, making his name come out "666," and the latter's champions fastened it upon Martin Luther, corrupting his name in the process. By this influence numerology was transferred from science to theology, though it pretends to both sanctions.

Returning to the Pythagorean tradition, it appears that in the course of numerological study important principles and relations of numbers were discovered, not so directly, numerology gave an impetus to mathematics, as astrology did similarly to astronomy and

alchemy to chemistry. All these pseudo-sciences proceed in the same mystical temper, the same devotion to ambitious generalizations, the same slant toward reading character and human fate. It is only in their degenerate forms that they become fortune-telling systems.

Numerology is pseudo-science on the basis of numbers. A typical idea is that of recurrence, the notion of cycles which, transferred to the cosmos, would eventually mean that everything that happens once will in due course happen again. The analogy was found in the recurring decimal 210210210 "To a gin free rationalist it is incredible that brooding on this eternal recurrence could ever have driven an educated man mad, but it did." For in this is the seed of the reincarnations and other doctrines associated with Pythagoras. The numerical side of numerology developed useful knowledge of number-relations, such as primes and squares. But for each discovery there was in turn a misleading numerological setback. Thus 220 and 284 were an "amicable number pair," in that each has the power through its divisors to generate the other.

The popular association of properties and fates with numbers—3's and 7's and again 13's, and all the variety of number superstitions—though they proceed on a history of their own—have a common root in Pythagorean notions, still surviving in the expression: a "square deal," which is both quadrilateral and just. The most famous numerological statement of old is the paragraph of Plato in which he describes the "nuptial" number.

> Whose base, modified, as four to three, and married to five, three times increased, yields two harmonies: one equal multiplied by equal, a hundred times the same: the other equal in length to the former, but oblong, a hundred of the numbers upon expressible diameters of five, each diminished by one, or by two if inexpressible, and a hundred cubes of three.

This mysterious calculation results in the number 12960000; it remained for a woman mathematician, Mrs. Young, in 1928 to discover how Plato derived it.

Derived forms of numerological thought, according to Professor Bell, abound in modern mathematics. Isomorphism is one of them and extrapolation another; and each is an example of the central numerological fallacy which is thus tersely put: a map is not the thing mapped. Identifying the map with what it represents, the number or the name with the thing, thus comes to be the major fallacy of pseudo-science, which I have ventured to call "attributism."

I can not present all the varieties of consequences which Professor Bell derives from his important thesis. I can only promise his readers a number of surprises and a most amusing occupation. The combination of mathematics and humor is rare enough to be noteworthy. In this "Numerology" we have a brilliant exposition of a novel approach to an important chapter in the history of science. "Numerology" is too good a word to lose. In the dictionaries of the future, it will be defined as that form of pseudo-science which ascribes all manner of virtues and qualities to numbers. The several varieties of it, appearing from Gematria to the modern fortune-telling device, will be recognized as so many variations of a great mislead. It will hardly do to allow the last comer, who happened to invent the name, to patent the word merely because he devised the most ridiculous example in the long line of descent. Numerology, as the opposite of science, is a concept of enduring worth to the study of logic.

The problem remains for the psychologist to discover "why our bedivilled race is more receptive to philosophy and numerology than it is to science and arithmetic." And still it is proper to honor Pythagoras.

"And so Ave atque vale, magister Pythagoras, alter ego! Our science is your shadow stripped of its numerology."

# SCIENCE SERVICE RADIO TALKS

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## CHEMISTRY AND RECENT MEDICAL PROGRESS

By Professor JULIUS STIEGLITZ

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FROM the inception of life to our return to dust, life consists of continuous chemical processes in which matter is transformed for the uses of the body. This close connection between life and chemistry makes chemistry a powerful instrumentality for progress in medicine. In recent years the greatest progress which has followed from this cooperation is undoubtedly in the domain of "the little things"—those extraordinarily powerful principles, the hormones and the vitamins, which are absolutely necessary for the healthful functioning of life. To-day's talk will be devoted to these "little things."

The hormones, produced in our own glands of internal secretion, and the vitamins, produced in plant life and taken into our bodies in our food, are perfectly definite chemical principles or compounds—as definite in their composition and actions as are such well-known drugs as morphine, quinine and strychnine.

Chemistry's first function has been to isolate these mysterious and powerful agents as pure crystalline compounds, exactly as one of its great contributions to medicine in the past was to isolate from crude drugs the pure alkaloids. These pure principles, strychnine, atropine and many others, gave physicians the opportunity of using exact doses to secure perfectly definite effects in place of haphazard results with the crude drugs; it became possible by hypodermic or intravenous injections to obtain almost instantaneous results. We are now witnessing the extension of this mastery of the situation in the use of the hormones.

Thus, epinephrine, or adrenalin as it is more frequently called, is the first of the hormones isolated by chemistry, by that great leader, John J. Abel, of the Johns Hopkins University; its availability in the form of pure crystals has saved many a life. Stillborn babies have been revived by its aid and saved for normal and useful lives. One instance of my own personal knowledge may interest you. A mother lay ready for childbirth in the Chicago Lying-In Hospital but with a heart too weak for the strain. Her heart had actually stopped beating and the eminent obstetrician faced the necessity of sacrificing the mother to save the child by a Caesarean section, but he allowed one minute more for an injection of epinephrine. The heart responded, the mother revived, and with the support of epinephrine passed through her ordeal. To-day both mother and child are alive and well, thanks to Abel and his tool, chemistry, and to up-to-date courageous medical care. Note that these signal services of medicine have been made possible only by the isolation of the pure crystalline principle to be injected in sterile solution hypodermically, intravenously or even into the heart, at the will of the physician. The dose of this powerful drug is one milligram, less than the weight of an ordinary particle of salt.

After isolating a pure hormone chemistry determines what we call the structure of the molecules of the principle—that is, the exact manner in which the atoms of carbon, hydrogen, oxygen and nitrogen are linked together. This the chemist does by a study of the fragments when he breaks up the principle and by a reconstruction of the molecule. The way is thus opened to the artificial preparation of the vital principle. This has been done for epinephrine, and the artificial compound is in common use. This study of the structures of hormones may well lead to attempted improvements on Mother Nature's products. A famous illustration of this possibility is the local anesthetic cocaine, an invaluable aid in surgery. The knowledge of the structure of cocaine led to the artificial drug novocaine or procaine, which is less poisonous than cocaine, very much cheaper and not habit-forming, as cocaine is. Thousands of operations are now carried out under the influence of procaine and similar creations of the chemist. In a similar way man's intelligence may endeavor in time to improve on blind nature's hormones; the results might be of inestimable benefit to individuals and to the race.

Epinephrine is found in the medulla of the adrenal glands, small glands located just above the kidneys. In the last years the attention of medicine has been directed intensively to a second hormone found in the cortex of the gland. Degeneration of the cortex causes Addison's disease, a wasting, hopeless disease. Many chemists and medical men have sought for the active principle of the cortex. In September, 1931, Dr. F. A. Hartman, of the University of Buffalo, electrified the world by describing the effects of a particularly active extract of this principle, which he named cortin. Thus, an apparently lifeless man suffering from Addison's disease was first revived by an injection of epinephrine and then by treatment with cortin restored to partial health within three days. Cortin and similar extracts are now being used regularly in hospitals. There is another side to the story of primary interest to chemists and the public. Cortin is so scarce that the adrenals of 50 to 150 head of cattle yield only a single day's dosage for a sufferer from the disease. The dose costs six dollars. It is vital that chemists isolate the absolutely pure principle and without delay determine its molecular structure so that efforts for its artificial production can at once be started. I understand that Dr. E. C. Kendall, of the Mayo Foundation, has made important progress in this direction.

Kendall, in 1915, discovered the crystalline principle thyroxine, the most important hormone in the thyroid gland, and he demonstrated that a dosage as small as a pinhead a day for a year was sufficient to change a poor little cretin, dwarfed in mind and body, into a healthy, happy and normal child. In 1926, Harington, in London, succeeded in determining the structure of its molecules, and within a year Harington and Barger prepared the hormone artificially. Synthetic thyroxine is now used in medicine.

The story of the hormone insulin, the sugar-consuming principle of our blood, is too well known to require more than brief comment. It has saved and prolonged the lives of hundreds of thousands of diabetics. The pure hormone was finally prepared by the veteran Abel, of the Johns Hopkins University. Unfortunately its molecular composition and structure are very complex. It will probably be a matter of years still before complete chemical knowledge will make possible its artificial preparation and open the way to carefully planned efforts to improve on nature's handiwork. The most pressing need of improvement is to discover a substitute which can be taken by mouth rather than by hypodermic injection.

The most decisive progress has recently been made in the isolation of the sex hormones, especially those of the female organism. There seem to be no less than five of these involved in its characteristic activities. One of these principles is especially well characterized chemically and biologically. It was first isolated by an American, Dr. Doisy, of St. Louis University, who named it theelin. It contains no sulfur or nitrogen and its molecule contains 42 atoms of carbon, hydrogen and oxygen. Injection of such minute quantities as 1/8000 of a milligram (two millionths of a grain) in unsexed white rats develops normal sex activity. As an indication of what the future may hold for us when synthetic chemistry may attempt to modify and improve on hormones, a fact observed by Butenandt is noteworthy, namely, whereas natural theelin is effective in an animal for three days, its benzoyl ester, an artificial derivative, is active for eleven to sixteen days—probably as a result of a slower elimination.

Theelin is already used in medical practise: in a tragic case of dementia following the exhaustion of childbirth, after years of ineffectual treatment and hospitalization, theelin at last has given beneficial results. In a similar fashion extracts of ovarian principles are often found beneficial in relieving the high blood pressure and similar effects of the menopause in women.

The possibilities of hormone therapy in the alleviation of certain mental diseases in general are most encouraging. Dr. Hoskins, of Harvard, has reported that five out of eighteen victims of the dread disease dementia praecox were so benefited by the thyroid hormone that they could be discharged from treatment. The sooner chemistry offers medicine the pure hormones, so that exact therapy can be used, the more rapid will be the progress in offering the body the perfect balance of these powerful agents which our complex organization demands.

The same type of progress in the cooperative efforts of chemistry and medicine is to be observed these days in the field of vitamins. Vitamin A, found in butter and fish-liver oils, has been isolated by Professor Karrer in Switzerland and the structure of its molecule has been determined. There should be no unusual difficulty in preparing it artificially. A Nobel prize was awarded to Professor Windaus, of Göttingen, for the isolation of the pure anti-neuritic principle, vitamin B, as obtained from yeast, and of vitamin D, a specific for the cure of rickets in children. Vitamin C has also been isolated in pure form by two or three independent investigators. The effectiveness of these pure principles is astonishing: thus ergosterol, the chemical precursor of vitamin D, in doses as small as 1/50,000 of a milligram, cures rickets in a mouse—that is, there would be perhaps 200,000 mouse-doses in a particle the size of a grain of salt. All these principles should soon be available for medicine.

In conclusion, let me say that among the great problems facing the alliance of chemical and medical investigation is the discovery of how these powerful principles, hormones and vitamins, bring about in such minute quantities their marvelous effects. Do they start a train of reactions like a match applied to a fuse? Do they unlock doors as keys would? Or do they perchance act like express elevators in skyscrapers, acting on small units, over and over again, with marvelous speed, thus facilitating the transformation of matter which spells life? The field is a fascinating one for scientific investigation and of the very greatest importance for medical control of life and health.

# PESTS AWAY FROM HOME

By Dr. L. O. KUNKEL

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DIFFICULTIES with plant disease and insect pests arise whenever anything is done which upsets those wonderful relationships known as the balance in nature. When, for example, a disease or insect pest is accidentally carried from its native home to a new country, it frequently upsets the balance existing among the species in that country. In 1904 a fungus disease known as "chestnut blight" was found to be killing chestnut trees in the vicinity of New York City. From the port of New York, into which it is believed to have been introduced from China, the disease has spread throughout most of the eastern states. In this vast region not a single tree of the native American chestnut is known to have escaped infection, and not one has been found which successfully resists the disease.

It takes about ten years for the blight fungus to destroy all the chestnut trees in any area which it invades. At the present time it is killing the last of the chestnut forests in the southern Appalachian Mountains. Here the chestnut represents about 25 per cent. of the forest stand over an area of about thirty-three million acres. The chestnut trees in this region occupy about 3½ million acres, and if harvested would yield about fifteen billion board feet of lumber. Millions of dead trees still stand in the forests through which the blight fungus has passed. If harvested promptly these trees yield a good grade of lumber. They may also be used for the production of extract wood, pulp wood and fire-wood. Many of them, however, can not be harvested promptly. They must be left to rot and are a total loss.

As the blight spreads from region to region by means of innumerable tiny wind-blown spores, the question arises as to whether the native American chestnut, *Castanea dentata*, will eventually become extinct. In the mountains of Pennsylvania, and in some other areas where the chestnut did not grow to be very large, a considerable number of trees have not been killed outright. The above-ground portions are dead, but the roots and crowns have remained alive, and have sent up strong shoots. Many of the shoots have become infected and have been killed, but many others, either because they have escaped infection or because they possess a certain degree of resistance to the fungus, have reached considerable size and have borne a few nuts. If some of these nuts should produce trees that are more resistant than their parents, and these trees in turn should give a progeny of varying resistance, it is possible, since only the most resistant would survive and produce nuts, that the species may in time reestablish itself in the forests from which it has been swept. The final outcome of the struggle which the chestnut tree is waging against extinction by the Chinese blight disease can not be predicted at present.

If, now, we inquire into the behavior of this terrible blight fungus in its native land, we find that it does not cause a serious disease of the chestnut trees there. When at home it lives on the Chinese hairy chestnut, *Castanea mollissima,* which is a close relative of the American species. These trees are not badly injured by the disease. This is doubtless because the Chinese chestnut, having been parasitized by the blight

fungus over a very long period of time, has developed a resistance sufficient to hold it in check. The American chestnut, having had no previous contact with the disease, has developed no resistance. Crosses are being made between susceptible American chestnuts and resistant Chinese trees. It may be possible to obtain hybrids having most of the good qualities of the American species combined with resistance to blight shown by Oriental species.

Two years after the chestnut blight was found near New York City, another foreign tree parasite was discovered at Geneva, New York. This pest, which is also a fungus, attacks all the eight species of native American white pines. It is known as the "white pine blister rust." It is impossible to estimate the damage which this parasite has already done. Many pine trees of great commercial value have been destroyed. Many others, occupying large areas of forest lands in thirty-eight states, are threatened with destruction. Millions of dollars have been spent in attempts to hold it under control. Nevertheless, it has spread throughout New England and into the states of New Jersey, Pennsylvania, Michigan, Minnesota, Wisconsin, Washington and Oregon.

Like the chestnut blight fungus, the blister rust spreads by means of small spores. On germination the spores produce the parasite which usually infects twigs at the bases of the leaf fascicles. From the small twigs it grows into the large branches and often into the trunk. It kills the trees by girdling them.

In one important respect this parasite differs greatly from that of the chestnut blight. It belongs to that interesting group of fungi which require two entirely different kinds of host plants. In order to complete its life cycle, the white pine blister rust fungus must find a currant or a gooseberry bush as well as a pine tree on which to live. Spores produced on pines are able to infect currants and gooseberries only. They do not infect other pines. The disease can not, therefore, spread directly from pine to pine. The spores produced on currants and gooseberries infect pines; but if no currants or gooseberries are available, the fungus can not go on to the pine trees. This dependence on currants and gooseberries is a vulnerable point in the life of the blister rust parasite. If all the currant and gooseberry bushes growing in the vicinity of a white pine forest are destroyed, the fungus can not attack that forest. Eradication of these bushes, which are of course less valuable than pine trees, is the most effective means known for controlling the blister rust. The chief weakness of this control measure is the difficulty of finding and killing all currants and gooseberries, especially in regions where these bushes grow as wild plants.

A parasitic fungus, *Tuberculina maxima,* has recently been found attacking the white pine blister rust in this country and in Canada. It lives on the spores of the rust and destroys them. Good results have been obtained in controlling the blister rust in some European forests by means of this natural enemy. It may become effective in holding the disease in check in certain parts of the United States. This example of a parasite living on another parasite furnishes a good illustration of the complicated relationships existing in nature. All living things, including the parasites which cause disease, are subject to attack by other living things.

Those who have studied the rust parasite believe that it, like the chestnut blight fungus, is of Asiatic origin. Instead of coming directly from Asia, as the chestnut blight fungus is supposed to have done, it is believed to have reached America by way of Europe. The blister rust is endemic in western Siberia, where it causes a mild disease of *Pinus cembra,* a pine native to that region. This species, having been ex-

posed to the parasite over a long period of time, has acquired sufficient resistance to hold it in check. Our white pine species are equally resistant to most of the pine diseases endemic in this country. They have, however, had no opportunity to develop resistance to foreign parasites such as the blister rust.

The chestnut blight fungus is believed to have reached this country on chestnut trees imported from China, the blister rust fungus on white pine trees imported from Europe. If these parasites had caused severe and conspicuous diseases in Asia, they might never have escaped from that country. The mildness of the diseases they produce there prevented their being recognized and eliminated from trees selected for export. Both reached this country before the enactment of plant quarantine laws.

These two diseases which have cost us so much indicate how dangerous it is to permit the entrance of foreign plant diseases into this country. Equally striking examples of foreign insect pests which have become established here and are doing much more damage than they were ever known to do in their home countries could be cited if time permitted. A similar behavior might also be described for some of our own native pests which have become established in Europe and elsewhere. Obscure and seemingly harmless insects may, when brought into any new environment, so upset the balance in nature as to become veritable scourges. Likewise, diseases which are almost, if not quite, harmless in their native lands frequently misbehave in the most alarming fashion when taken away from home.

# THE EARLY IRISH RACE

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THE racial history of Ireland still awaits serious investigation. Much that was written up to about fifty years ago about Phoenician and Spanish strains in the Irish people was based on insecure legends or even on fancies of the flimsiest kind. This brief talk will not deal with any elements that may have reached Ireland since the fifth century of our era, but will confine itself to the ancient constituents of the Irish people in St. Patrick's time, as far as these can be distinguished at the present moment.

For the earliest period, information can be obtained only from the examination of very ancient skeletal remains revealed by excavations. Such discoveries have been relatively few, for systematic investigation remains to be carried out. Altogether, hardly five hundred skeletons or skulls have been found. But nearly 80 per cent. of the oldest skulls are either long or medium in proportion to the width, and the older the skulls, the greater the percentage of long ones. Broad or round skulls do not appear in any numbers till far into the Christian era. I may note that long skulls are those whose width is less than three fourths of their length; broad or round skulls have a width of four fifths or more of their length; those in between are called medium.

As to stature, the indications are that these early skeletons are short to medium: for men, they vary from 5 feet 5 inches to 5 feet 9 inches; for women, from 5 feet to 5 feet 5 inches. As to the color of complexion, hair and eyes, of course no traces of such traits can be left after a lapse of four thousand years.

The presence in Ireland, two thousand

years before the Christian era, of a medium-statured race with medium-shaped skulls is quite in harmony with the discoveries made on the continent of Europe. There it is found that the "chipped-stone" or "paleolithic" age is associated with long skulls, but that at the end of this period some broad skulls appear, and that during the succeeding "polished-stone" or "neolithic" age these broad skulls become more frequent while also a mixed type, like that of the Irish skulls, appears.

The long skulls are ascribed to the "Mediterranean" race, which is medium in stature and dark in complexion, hair and eyes. The broad skulls are ascribed to what is now called the "Alpine" race, which shows lighter coloration and stockier build than the "Mediterranean," but is like it in its medium stature. At a later period the "Teutonic" race appears, with all the traits attributed by the Greek and Roman writers to the Celts and Germans, namely, a combination of long-headedness with tall stature and fair or reddish hair and blue eyes. By the mixture of the "Mediterranean" and "Alpine" types arose the medium type of skull found in Ireland, as well as in England and on the continent. But the broad skulls found in the latter places are almost entirely lacking in Ireland. In Scandinavia, if Montelius is correct, the oldest burials show round skulls, and the later stone age burials show skulls of the Teutonic type.

Following the two stone ages came the "bronze" age, with weapons, tools and utensils of bronze, which gradually show an increasing perfection of design and especially of decoration. The bronze age is plentifully represented in Ireland, as it is all over Europe. In England, the use of bronze is associated with burials which contain round as well as long skulls. However, there is no appearance of any new type of human beings in Ireland along with this new kind of culture. It seems that the use of bronze was introduced by trade and not by the migration of people of another physical type; not a trace is found of any radical change in burial customs or in the kind of skulls or objects discovered. Besides, bronze had to be imported, or at least the tin that enters into its composition, for tin is not found in workable quantities in Ireland, although copper is. Tin, on the other hand, is plentiful in Cornwall. The people of Cornwall at a later date were called Dumnonii; if these were the same stock as the Irish tribe called Fir Domnann, it is possible that there was a migration from Cornwall to Ireland; but no reason is apparent for connecting this with the introduction of bronze into Ireland. On the other hand, we know positively that there was an extensive trade between Ireland and the continent during the bronze age, for Ireland had easily worked deposits of gold, especially in Wicklow, and certain types of gold ornaments—torcs and crescents—characteristic of Ireland are found scattered over Europe in bronze-age deposits, and even as far east as ancient Troy near the Bosphorus.

The bronze age appears to have lasted in Ireland from about 2000 till about 400 B. C. without any change in the physical make-up of the inhabitants. The use of iron began on the continent about 900 B. C. in the Danube Valley, in what was later called Austria. The first period of the iron age is called the Hallstatt period, and lasted till about 400 B. C. on the continent. But in Ireland nothing resembling Hallstatt implements is found, except occasional objects that stand out in contrast to a purely bronze-age culture. Their presence is explainable by trade. About 400 B. C. began, on the continent, the second phase of the iron age, called the La Téne period. The Irish iron-age objects belong clearly to this second phase of iron-age culture. Consequently, this culture developed in Ireland only after

400 B. C., and we kill two birds with one stone if we postulate the arrival of the Gaels somewhere about the middle of the fourth century B. C.

This supposition harmonizes with what we know of the people called Celts in central Europe. It is commonly accepted that if the Celts of central Europe did not themselves discover the use of iron in the Hallstatt region about 900 B. C., at least their neighbors, the Illyrians, did, and the Celts made good use of the discovery. Their expansion into Gaul probably took place between 900 and 600 B. C. This would explain the finding of iron weapons beside tall, long-headed skeletons buried beneath mounds in the Marne region. In the course of time they were amalgamated more and more completely with the primitive population of Gaul north of the Garonne, which was a mixture of the Mediterranean race with immigrants of the Alpine race, besides having absorbed remnants of the taller, long-headed, stone-age types. The ruling class still retained their tall and fair traits in Caesar's time, for that is how he describes the Gauls, probably referring to the leaders rather than the rank and file of the people.

Around 400 B. C. another period of expansion took place among the Celts of central Europe which brought them into Italy, where they occupied the Po valley, from which they advanced southward, capturing Rome in 390 B. C. The movement went on north of the Alps and seems to account for the presence in northern Gaul and in Belgium of the Belgae, who, according to Caesar, were fiercer and ruder than the Galli of the middle portion of Gaul. Some of the Celts taking part in this second irruption into Gaul seem to have entered Ireland by sea during the fourth century B. C., bringing with them the same types of iron weapons and utensils that characterize the Celts on the continent from about 400 B. C. down. It is not clear whether the Celts who entered Ireland at this time under the name of Gaels—anciently Goidels—were Belgae or men of the same type as the ruling class of the Galli. In any case, they seem to be characterized, in Ireland, by tall stature, long skulls and faces and fair hair—in other words, the Milesian type. There is evidence, however, that the Belgae did send colonies into Ireland, though perhaps at a later time. Ptolemy, the geographer of the second century A. D., gives us a map of Ireland on which are placed the names of certain tribes. On the eastern coast he sets the Manapii, which is also the name of a tribe in northeastern Belgium or western Holland. The name still lives in that of County Fermanagh. Several other names given by Ptolemy resemble those of tribes situated near the Rhine, some of them being perhaps German tribes.

These observations do not contradict the descriptions of races that we obtain from the old literature of Ireland. There we find frequent references to the tall stature, the long yellow, golden or reddish hair and the gray or blue eyes of the ruling classes and their heroes, in sharp contrast to the short, stocky build and the short black or brown hair of menials or of enemies in general. This shows the contrast between the Gaels and their predecessors in the country as seen by the Gaels themselves.

As to the Picts, the question is even more difficult. They were recognized as distinct in northeast Ulster up to the eighth century A. D., and were assigned also to several other parts of Ireland where they did not retain their identity. They also occupied Scotland, where they are mentioned historically from about 400 A. D. But as to their description and their relationship to the Caledonians and other peoples, we are entirely in the dark. Another race men-

tioned is that of the Fomoraigh, described as black, and as making piratical incursions from the north by sea. All we can say about them is that their name seems to mean "seashore folk" and to be the etymological equivalent of the German Pommern, which is from the Slavic Pomoře, meaning also "seashore folk." The Tuatha Dé Danaan, "the tribes of the goddess Danu," are a mythical people who really represent the gods of the old Pantheon; though it is true that some early writers describe them as a race of men.

As to the language spoken by the various racial types that go to form the Irish people, there is no evidence of any other language but Gaelic being spoken in Ireland during the historical period. In the old stories representatives of the various racial groups converse in friendly or in hostile fashion without any suggestion of a difference of language or even of dialect. In the case of the Picts of northern Scotland, there is mention later on that the missionary Columkille and his disciples had need of interpreters when they went to preach to them; while in southern Scotland—where the Picts were closely associated with the Scots, as the Gaels were called—there appears to have been no such need. There are also some inscriptions found in Scotland, thought to be Pictish, which have not yet been interpreted. In Ireland, no remains of a non-Celtic language are found, except in certain geographical names, like that of the Shannon River and some others. Does this indicate that the predecessors of the Gaels already spoke a Celtic language when they arrived in Ireland? I think not, for the pre-Gaelic population goes back without any serious interruption or change to the polished-stone age, at which time Celts are unknown, even in central Europe. The same may be said of the shorter element among the Celts or Gauls of the central portion of Gaul in Caesar's time, in spite of the fact that some ethnologists apply the name "Celtic" to the round-headed "Alpine" race which during the polished-stone and bronze ages mixed with the earlier long-headed "Mediterranean" race to produce the medium-headed, medium-statured, medium-colored race that is so much like the basic element in Ireland. There is no evidence that there were any Celts in existence at that time, nor at any time before 900 B. C. In the proper use of the term, the "Celts" are those who used a Celtic language; and the earliest descriptions we have of a people speaking a Celtic language make them tall and fair like the earliest Germans. While it is possible that the pre-Celtic population of western Europe used some other form of Indo-European language, we do not yet know what language was spoken either in Gaul or in Ireland before the coming of the historical Celts, into Gaul about 900 B. C. and again about 400 B. C., and into Ireland a little after 400 B. C. But these speakers of Celtic spread their language over the populations they subdued, and so completely that only the barest traces remain of any older language. In both cases a homogeneous people was produced, not indeed in the physical or anthropological sense, but in a linguistic, psychological, cultural and national sense. National unity rests, not on a physical basis, but on the basis of a common culture, a common historical development and a common ideal of life.

# NOCTURNAL DREAMS

By Professor WARREN C. MIDDLETON

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SCIENTIFIC data pertaining to dream phenomena are admittedly inadequate. The paucity of experimental studies upon the problem of dreams is chiefly due to the difficulty of applying experimental techniques; a scientific investigation of dreams by either objective or introspective methods is for obvious reasons exceedingly difficult. The content of dreams has been studied traditionally by the introspective and the questionnaire methods. Bentley,[1] for example, has achieved some rather meager, though valuable, results from an introspective technique, which he describes with considerable confidence. Introspection here, however, as elsewhere, has many limitations and imperfections. "It is almost impossible," suggests Morgan, "to get an experienced observer to narrate a dream without interpolating explanatory and organizing material."[2] Moreover, a study of dream content by introspection is largely a study by retrospection. Accordingly, Calkins remarks: "The difficulty of remembering dreams suggests, of course, the impossibility of an exhaustive enumeration of their peculiarities and any positive conclusions from the figures. . . ."[3]

The present discussion attempts neither to set forth an experimental technique nor to suggest a theoretical approach to the problem of dream content; nor is it concerned with the etiology of dreams. It merely deals with the reporting of a few interesting facts derived from a questionnaire-census of the ordinary dream experiences of a limited number of unselected college students, enrolled in various psychology courses. Originally, this material grew out of a much more comprehensive survey, which dealt with psychopathic and psychoneurotic tendencies, and sleep phenomena other than dreaming. Only those items pertaining to nocturnal dreams will be considered here. The subjects used in this study comprised 170 college students—81 men and 89 women. All of them had sometime previously been given two class lectures on the limitations and the inadequacies of subjective methods of securing psychological data, and they had been properly advised of the necessary precautions to be taken in the use of such methods. Furthermore, a majority of the subjects had been instructed previously in one of their psychology courses concerning the special limitations of the questionnaire method of investigation. Thus, every possible step was taken to prevent any unnecessary abuse of the techniques to be used.

The subjects were first informed by the examiner of the nature of the questionnaire. They were repeatedly told that the data were to be used for statistical purposes only. They were urged to use the utmost caution, and they were instructed that, in no case, were they to answer any question unless they were fairly positive that their answers were correct. Finally, they were assured that their answers would be kept strictly confidential, inasmuch as their names were not to be affixed to their papers.

The general procedure was as follows: The questionnaire items were dictated by the examiner instead of being distrib-

[1] M. Bentley, "The Study of Dreams; A Method Adapted to the Seminary," *Amer. Jour. Psychol.*, 26: 196–210, 1915.

[2] J. J. B. Morgan, "The Psychology of Abnormal People," p. 406. New York: Longmans, Green and Company, 1928.

[3] M. W. Calkins, "Statistics of Dreams," *Amer. Jour. Psychol.*, 5: 312, 1892–93.

uted in mimeographed form. Six blank sheets of paper were placed in the hands of each subject. At the top of the first blank sheet the subject was told to signify his age, collegiate classification and sex. The items of the questionnaire were then dictated by the examiner, each item being read twice. The subjects were carefully instructed not to answer any question until they were told to do so, and from one to two minutes were allowed for each questionnaire item.

The subjects gave their answers to each question in accordance with the specific instructions of the examiner, and at a specified time. For each questionnaire item the examiner took sufficient time to clear up any ambiguous terms or misconstrued meanings. In spite of such careful instructions, however, several subjects failed in many instances to respond according to directions (as is usually the case in a questionnaire survey of this kind), and their answers had to be ignored statistically.

The questionnaire items appear below, but space does not permit the statistical tabulation of results, with responses for each sex and totals for both sexes.

*THE QUESTIONNAIRE*

1. (a) Do you dream?
   (b) About how much?
2. Do your dreams appear to be simple or complicated?
3. (a) Do you have fear dreams?
   (b) About how frequently?
4. Are you usually an active participant in your dreams?
5. Would you say that your dreams usually contain some element from the experience of the previous day?
6. (a) Do you have dreams which seem to "come true?"
   (b) To what extent?
7. Do you have dreams of soaring, falling, or flying?
8. (a) Do you have dreams of frustrated effort?
   (b) How common are such dreams?
   (c) Would you judge yourself as having an inferiority complex?
   (d) Do your dreams of frustrated effort seem to be related in any way with your inferiority complex?
9. (a) Do you ever dream of being nude?
   (b) How common are such dreams?
   (c) Does this kind of dream seem to cause you any special embarrassment?
10. (a) Do you sometimes dream of a dead person returned to life?
    (b) Are these dreams inclined to be recurrent?
    (c) Do you usually dream of the same person?
11. (a) Do you sometimes dream that some dead person has never died?
    (b) Are these dreams inclined to be recurrent?
    (c) Do you usually dream of the same person?
12. (a) Do you sometimes dream of the death of some relative or friend, now living?
    (b) Are these dreams inclined to be recurrent?
    (c) Do you usually dream of the same person?
13. (a) Is visual or auditory imagery more frequent in your dreams?
    (b) Do you get any color imagery in your dreams?
14. Are your dreams usually pleasant or unpleasant?
15. Do you believe that you do any thinking in your dreams?
16. Do your dreams usually seem to take up considerable time?
17. Do you believe that you ever remember any dreams which do not cause you to wake up?
18. Are you inclined to worry much about your dreams?
19. Do any of your dreams seem to be influenced by strong desires?
20. Are your dreams usually absurd?
21. Are your dreams dismissed from your mind easily and quickly, or is there a tendency to remember them for some time?
22. (a) Are you inclined to tell your dreams to friends?
    (b) Does the mere "telling" seem to give you a feeling of relief or satisfaction?
23. Do any of your dreams seem to contain a feeling of future significance?
24. Did you ever have a dream of paralysis?
25. (a) Do you have recurrent dreams?
    (b) How regularly?
26. Would you say that any of your dreams appear as an imaginary fulfillment of a repressed sexual wish?
27. Are you ever able to trace any of your dreams back to some special stimulation of the body surface during sleep?
28. Do your dreams often violate your moral principles?

29. Do you consider any of your dreams as in any way supernatural?
30. Do your dreams ever seem to result from prolonged anxiety?
31. (a) Do you day-dream a great deal?
    (b) Does the content of your day-dreams seem to be closely related to the content of your nocturnal dreams?
32. Do you think that any of your dreams have ever produced in subsequent waking activity any of the following:
    (a) Any prolonged moods?
    (b) Any false recollections?
    (c) Any fears?
    (d) Any delusions?
    (e) Any obsessions?
    (f) Any conduct disorders?

Only a very meager portion of the results obtained from the foregoing questionnaire can be reported here. In general, the data demonstrated that there was not any one essential aspect or attribute common to the dream activity of all individuals—a feature that must always be present. Each dream seemed to be unique and individual in some particular aspect or aspects. The matter of individual differences was, therefore, very apparent; there were great individual differences among individual dreamers.

The data also indicated that sex differences, if they existed at all, were not sharply enough differentiated to be considered very significant. Twice as many men as women reported that they dreamed of being nude; they had such dreams much more frequently and the dream of nudity caused them much less embarrassment. Women were inclined to tell their dreams to friends almost twice as much as men. About twice as many men as women reported that their dreams appeared to be an imaginary fulfillment of a repressed sexual wish. More men than women also reported that their dreams often violated their moral principles. These few differences, mainly of a sexual character, were clearly evident; but the number of cases (170) was so few that it would be extremely hazardous to draw any definite conclusions as to sex differences from such limited data. The general trends are suggestive, but there is the possibility that, if the cases were greatly increased, the sexes might show considerably less differentiation—perhaps no differentiation at all.

The data demonstrated certain other general tendencies, however, and some of the more interesting trends indicated by the questionnaire were:

(1) The subjects were almost unanimous (99.4 per cent.) in saying that they dreamed, but they differed greatly in the amount of dreaming. The assumption that sleep is usually dreamless is certainly not borne out, and, as Fisher has suggested, "is really without the slightest factual basis to support it."[4] De Sanctis and Neyroz[5] have, in the opinion of the author, presented very logical data for postulating a continuity of mental activity during sleep.

(2) Sixty-nine per cent. (69.4 per cent.) of the subjects reported that their dreams were complicated rather than simple. This might be expected of adult dreams, although, according to one investigator,[6] the dreams of children appear to be very simple and direct, consisting often of mere imaginary wish fulfillments.

(3) Ninety-two per cent. (92.9 per cent.) of the subjects reported that they were usually active participators in their dreams. This reveals nothing new or unusual. In fact, it is generally contended that a child is practically always a very active participant in the dream situation—an adult, only a little less so.

(4) Only a very small majority (51.2 per cent.) of the subjects reported that their dreams usually contained some element from the experience of the previous day. This does not support the

[4] V. E. Fisher, "An Introduction to Abnormal Psychology," p. 379. New York: The Macmillan Company, 1929.

[5] S. De Sanctis and U. Neyroz, "Experimental Investigations concerning the Depth of Sleep," *Psychol. Rev.*, 9: 254–282, 1902.

[6] C. W. Kimmins, "Children's Dreams," New York: Longmans, Green and Company, 1920.

wide-spread belief of those who say that a dream invariably contains some aspect of the previous day's experience (the day followed by the night of the dream), although as some observers have noted, this may be true in the dream experience of the child.

(5) Eighty-nine per cent. (89.5 per cent.) of the subjects reported that they had dreams of frustrated effort, though these dreams were not especially frequent. This questionnaire might indicate that such dreams are perhaps more common than is generally supposed, particularly among many types of psychoneurotic personalities. Indeed, a very careful analysis might possibly indicate that a large percentage of all our nocturnal dreams should be classified, basically and fundamentally, as dreams involving the element of frustrated effort.

(6) Thirty-three per cent. (33.9 per cent.) of the subjects indicated that they had dreams of being nude, though such dreams were not especially frequent. The subjects were about equally divided upon the question of embarrassment caused by a dream of nudity. These data may indicate that the great stress upon "utter lack of embarrassment" accompanying such dream experiences, which has been so much emphasized by certain modern writers, is probably exaggerated and has no real factual basis.

(7) Ninety-six per cent. (96.3 per cent.) of the subjects reported visual imagery to be more frequent in dreams than auditory imagery. This much greater proportion of visual imagery supports the findings of practically all investigators of dream phenomena. Calkins,[7] for example, found visual images to be related to auditory in the ratio of 3 to 2. Bentley[8] also found visual images slightly more frequent in the dreams of his subjects than auditory—visual 59, and auditory 51. Morgan summarizes the literature on the subject in the following generalization: "Investigations have shown that by far the greater proportion of dreams are visual. Less than half as many are auditory."[9]

(8) Seventy-four per cent. (74.4 per cent.) of the subjects reported that they did not get any color imagery in their dreams. In like manner, Bentley[10] found that colors appeared in the dreams of his subjects occasionally (11) but that gray imagery was the rule (48).

(9) Sixty-six per cent. (66.6 per cent.) of the subjects were inclined to the belief that they did thinking in their dreams, which is a conclusion quite contrary to the generally accepted view that all thought processes are in abeyance during sleep. These data seem to be in agreement with the findings of Bentley, who comments: "We are told that 'people' do not think in dreams, that dreams are wholly irrational, that incongruities are not recognized, that dreams do not pursue a given topic, and what not. In our own introspections we found not one of these generalizations to hold."[11] However, Bentley is careful to add that "thinking is rare and, as a rule, ineffective."[12] To be sure, Coleridge, according to his own account, got his inspiration for *Kubla Khan* in an opium dream; and Tartini, the celebrated Italian violinist, is said to have told Lelande that he composed the sonata, *Ill Trillo del Diavolo,* or "The Devil's Sonata," as the result of a dream. Likewise, there are many reports of difficult problems having been solved during dream activity, but one is necessarily led to conclude that thinking is very ineffective in the dreams of most of us.

(10) A majority of the subjects indicated that their dreams were inclined to be pleasant rather than unpleasant. This affective element of pleasantness is in keeping with the Freudian interpretation of dreams. However, it does not

7 *Op. cit.,* 321.
8 *Op. cit.,* 202.

9 *Op. cit.,* 405.
10 *Loc. cit.*
11 *Op. cit.,* 208–209.
12 *Op. cit.,* 209.

bear out the investigation of Bentley,[12] who found unpleasant dreams to appear about twice as often as pleasant ones.

(11) Seventy-four per cent. (74.8 per cent.) of the subjects reported that dreams were dismissed from their minds (forgotten) easily and quickly. Morgan suggests that "this tendency to forget is not confined to unpleasant dreams but may affect pleasant ones or indifferent ones as well."[14]

(12) Forty-four per cent. (44.6 per cent.) of the subjects reported that dreams had produced prolonged moods in subsequent waking activity. This tendency has been clearly recognized by Conklin, who remarks: "The emotional accompaniment of a dream often carries over into the day following and serves to produce a mood of considerable duration."[15] This may be true especially of psychoneurotic personalities, who are ever inclined to confuse their dream past with their waking past.

(13) Thirty-six per cent. (36.4 per cent.) of the subjects reported that dreams had produced false recollections in subsequent waking activity. It does not seem at all unreasonable that this should happen rather frequently. "It is highly probable," says Sully, "that our dreams are, to a large extent, answerable for the sense of familiarity that we sometimes experience in visiting a new locality or in seeing a new face"[16] (paramnesia).

(14) Only a very small number of the subjects (5.9 per cent.) reported that dreams had produced conduct disorders in subsequent waking activity. This percentage may be slightly too high, inasmuch as some of the subjects were possibly confused as to the exact meaning of "conduct disorder." However, that such a thing is possible would, of course, not be denied. Prince[17] describes a very interesting case, reported by Dr. G. A. Waterman, in which, under complete hypnosis, an instance of kleptomania could be traced back to a dream which had occurred one and one half years previously.

As has been emphasized throughout, this questionnaire report is in no sense extensive enough to base conclusions upon, but it does point out to the student of dream phenomena certain interesting trends and tendencies, which, for the most part, have been substantiated both by one's own experience and by the investigations of a few experimenters. The chief methods available for clearing away popular superstitions and fallacies relative to dream content would seem to be (1) the extensive study of large numbers of children and adults by the questionnaire-census method; and (2) the intensive introspective study of sufficient numbers of subjects under controlled conditions. In any event, the author believes that the questionnaire-census, with all its serious defects and limitations, has some value in the statistics of dreams, when used to supplement the data procured by other more refined methods.

[13] *Op. cit.*, 203.

[14] *Op. cit.*, 409.

[15] E. S. Conklin, "Principles of Abnormal Psychology," p. 329. New York: Holt, 1927.

[16] J. Sully, "Illusions," p. 274. New York: D. Appleton and Company, 1897.

[17] Morton Prince, "Coconscious Images," *Jour. Abn. Psychol.*, 12: 307–310, 1917.

# "PEARL" FARMING IN JAPAN

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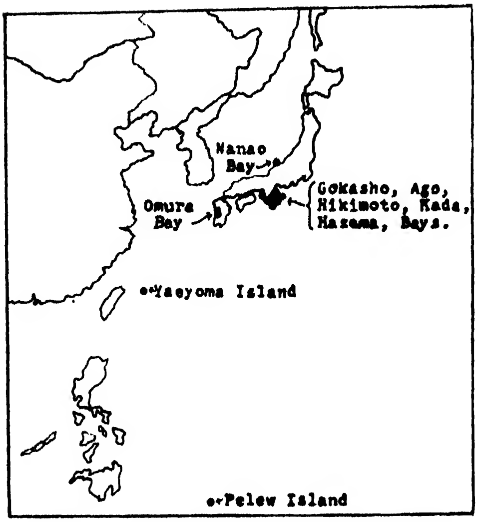



FIG. 1. CULTURE PEARL FARMS

### Japan Must Needs Look to the Sea

The presence of a dense and rapidly growing population in a land of meager resources has compelled the Japanese to carry on an unusually thorough exploitation of the surrounding seas. To this end they have built up one of the world's greatest merchant fleets, they maintain a powerful navy, and they, of all nations, are most dependent for a food supply upon the fisheries. Fish rank next to rice in their diet and the annual per capita consumption of 82 pounds gives them undisputed first rank as the world's greatest consumers of sea food.

Of the various activities designed to wring the utmost of sustenance from her waters, none is more unique or interesting—none, indeed, more spectacular—than the recently perfected method of producing on a large scale the so-called "culture pearls." The story of this accomplishment adds another interesting chapter to the series of triumphs of the scientist in his effort to improve on the crude and ofttimes wasteful methods of nature.

### Pearls as the Fisherman's Quarry

Until a little over a decade ago, the genuine oyster pearls of commerce represented the combined harvest from thousands of pearl divers working in the out-of-the-way corners of the tropic and sub-tropic seas. The bulk of them came from the coastal waters off Asia, in particular those reaching from the Red Sea around to Japan. Like most returns from hunting and fishing, both

FIG. 2. CAGES WITH OYSTERS AFTER THE OPERATION

READY TO BE LOWERED INTO SEA FOR THE GROWTH OF PEARLS.

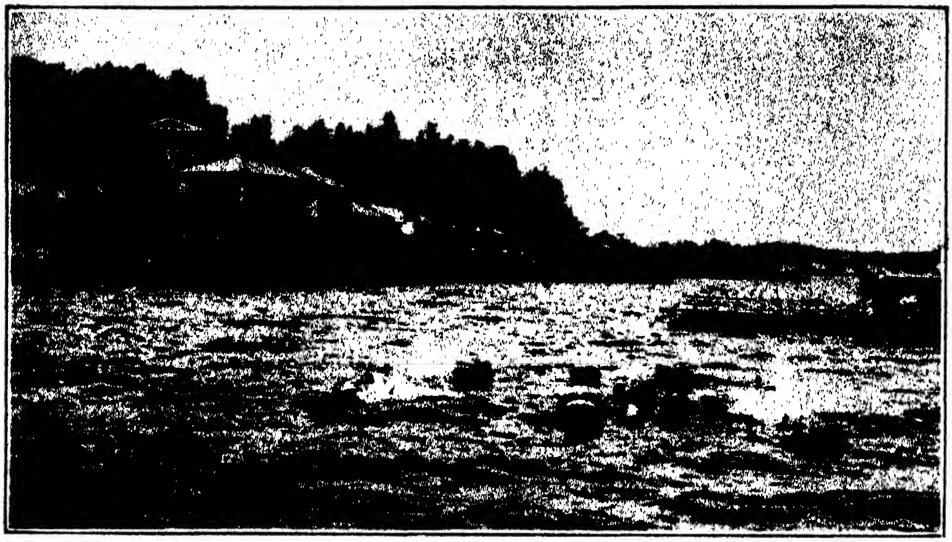


FIG. 3. AGO BAY
SHOWING THE BUILDINGS WHERE THE OPERATIONS UPON OYSTERS ARE PERFORMED.

the quantity and quality of the harvest were subject to marked fluctuations, and unrestricted exploitation had in many sections practically exterminated the oyster beds.

It remained for a Japanese scientist to remove the large factor of uncertainty in the pearl supply and to shift the industry into the category of man-controlled operations whose output could be regulated to suit the market needs.

### A Japanese Scientist Attacks the Pearl Problem

The evolution of the cultivated pearl industry represents the life work of Baron K. Mikimoto, the Japanese scientist upon whose researches the industry rests. Born in Toba, in southeastern Japan, where pearl fishing was the chief means of livelihood, he early became interested in the improvement of the gems by the selection and cultivation of the pearl oysters. By 1894 he had succeeded in producing semi-spherical pearls attached to the shells, and 9 years later, he was able to exhibit perfectly formed pearls. Shortly after the world war he began to market them, and each succeeding year has seen "Mikimoto pearls" playing a larger rôle in the world's pearl trade.

### Requirements of the Pearl Oyster

The requirements for the successful growth of the pearl oyster are rather exacting. The temperature of the water should preferably be above 68° F. (20° C.)—a drop below 50° F. (10° C.) being fatal. Furthermore, the waters should be clear and calm, the bottom clean, and there must be sufficient circulation to bring food and to remove waste. One of the most serious difficulties is the destruction of the oysters by their natural enemies—especially the octopus and starfish, so that freedom from these pests is necessary. Even if these conditions are all complied with, left to themselves, only a small fraction of the oysters actually produce pearls. Consequently, the interference of man is necessary, and we have the final important requirement of a cheap and efficient labor supply.

### Geographical Distribution of Pearl Farms

The waters of southern Shima, including Ago Bay, in southeastern Japan, are remarkably clear, the few tributary streams are almost devoid of sediment, and the bottom of the bay is sandy. Furthermore, the south end of the bay is open to the warm Kuro-shiwo or Blue Current, which flows north from Formosa and Luzon. Here Mikimoto has leased the island of Tahoku and has also acquired the rights to about 50 miles of the adjacent waters. Here he established his first "pearl farm." Since then, the work has expanded to include the other sites as shown on the sketch map, but Ago Bay remains the main center of the industry.

### How the Pearls Are Produced

Briefly put, the steps in pearl production are essentially as follows:

(1) Young oysters or "spats" about three years old are collected from the sea bottom in 30 to 40 feet of water by a crew of diving-girls (see Fig. 3). The great demand for "spats," with the consequent depletion of supply, has led to an ingenious method whereby the floating larvae are now captured and the spats raised.

(2) These young oysters are taken to a near-by building, where they are subjected to a very delicate operation by highly skilled technicians. This operation—the most critical step in the whole industry—consists in removing from one oyster the mantle parenchyma—a small sack—into which is inserted a tiny bead of mother of pearl. The mouth of the bag is then tied and the sack is inserted into the subcutaneous tissue—the shell secreting epidermis—of a second oyster through an opening surgically made. The cord is then removed, the wound disinfected and the oyster replaced in the sea to eventually cover the bead nucleus with several layers of nacre. For protection against its ene-

FIG. 4. CLEANING THE OYSTERS

TWICE A YEAR THE CAGES ARE RAISED AND THE OYSTERS CLEANED OF MUD AND VEGETATION.

FIG. 5. A 10-YEAR OLD OYSTER
SHOWING A CULTURE PEARL IN PLACE.

FIG. 6. DRILLING PEARLS
FOR STRINGING AT TOBA, JAPAN, NEAR A PEARL FARM.

mies, sudden changes in temperature and muddy water, these potential pearl makers are placed in wire cages and suspended from floating rafts, about 6.5 feet below the surface. When unfavorable conditions develop, such as storms or changes in the current, the rafts are floated into protected waters. Experience has shown that, on the average, they are compelled to move about twice a year.

(3) The oysters live in these cages for seven years, being drawn up once or twice a year and the shells cleaned of weeds and barnacles which hinder growth and sometimes even kill the oyster.

(4) At maturity, *i.e.*, at the age of 10 years, the oysters are removed from the cages, the pearls recovered, cleaned, sorted, and drilled for stringing. The oysters themselves are tasteless and are not used for food. However, the shells are used, part of them for the beads to be used for further pearl production.

## The Pearl Harvest

For several years an average of about 3,000,000 oysters were set to work annually, but in 1930 this was increased to 5,200,000 and in 1931 to 6,300,000. Experience has shown that about 20 per cent. die, principally as a result of the operation; a like number fail to produce pearls, leaving about 60 per cent. yielding pearls of various grades. Of these latter only the most perfect are sold under the name of "Mikimoto Pearls." About 600 pounds of pearls are now produced yearly.

The initial offering of these pearls produced a furore in the gem trade. Possessors of pearl stocks had visions of a flood of cultivated pearls which would demoralize the market and ruin prices. Legal steps were taken to bar the new product as an artificial imitation. Experts, however, found that there was no essential difference, that only by making a cross section could one be identified, since that would reveal the bead nucleus.

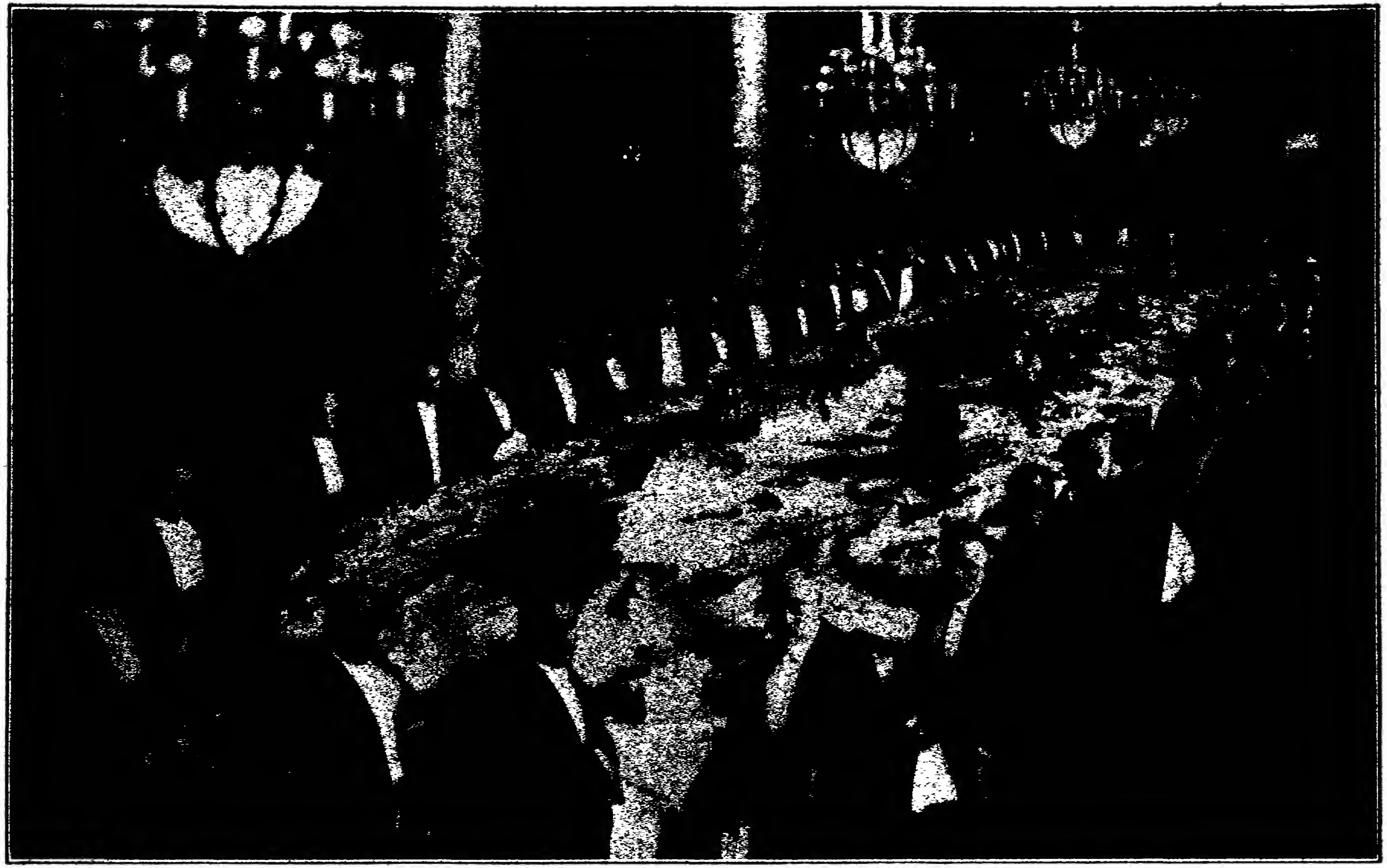
## Extent of the Industry

At present pearl farms to the number of ten are located as shown in Fig. 1. Their combined area totals about 40,830 acres, controlled under fishing licenses and leases. The industry employs about 1,000 workers and uses some 80 buildings. With the exception of a small output by lessees of Mikimoto's patents, the whole industry—production, manufacture, and sale—is in the hands of this one firm. They own some 17 patents covering the culture, cages, attachment of larvae, and even the regulation of the luster of the pearls.

## Importance of the Human Factor

Undoubtedly there must be vast numbers of waters in our tropic and subtropic seas as favorable for pearl oysters as those used. However, the protection of the many patents, the efficient closely knit corporation with its long experience and highly trained corps of workers, the abundant labor at a low wage scale[1] together with the long period of time which must elapse before the investment bears returns—these would seem to make the likelihood of successful competition by others remote. It is an excellent illustration of the dominant importance of the human over the environmental factor.

[1] The U. S. Bureau of Fisheries experimented with artificial pearl culture in fresh-water mussels and found that while possible, the expense involved made it commercially unpracticable. At the time of writing, March, 1932, the young women employed as divers for spats received an average of one yen, or 32 cents per day.



ANNUAL DINNER OF THE NATIONAL ACADEMY OF SCIENCES, WASHINGTON, APRIL 7, 1906

Alexander Agassiz, then president of the Academy, is presiding. On his right is Elihu Root, Esq.; Dr. William H. Welch; Henry Cabot Lodge, then senator from Massachusetts. On his left is Joseph G. Cannon, then speaker of the House; John S. Billings, then director of the New York Public Library, and Robert S. Woodward, then president of the Carnegie Institution.

# THE PROGRESS OF SCIENCE

## THE SCIENCE ADVISORY BOARD

By his Executive Order No. 6238 President Roosevelt has appointed a Science Advisory Board to consult with the United States Government on matters pertaining to science. The official communication reads:

The National Research Council was created at the request of President Wilson in 1916 and perpetuated by Executive Order No. 2859, signed by President Wilson on May 11, 1918. In order to carry out to the fullest extent the intent of the above Executive Order, there is hereby created a Science Advisory Board with authority, acting through the machinery and under the jurisdiction of the National Academy of Sciences and the National Research Council, to appoint committees to deal with specific problems in the various departments. The Science Advisory Board of the National Research Council will consist of the following members who are hereby appointed for a period of two years: Karl T. Compton, *chairman*, president, Massachusetts Institute of Technology; W. W. Campbell, president, National Academy of Sciences, Washington, D. C.; Isaiah Bowman, chairman, National Research Council, and director, American Geographical Society, New York City; Gano Dunn, president, J. G. White Engineering Corporation, New York City; Frank B. Jewett, vice-president, American Telephone and Telegraph Company, and president, Bell Telephone Laboratories; Charles F. Kettering, vice-president, General Motors Corporation, and president, General Motors Research Corporation, Detroit; C. K. Leith, professor of geology, University of Wisconsin; John C. Merriam, president, Carnegie Institution of Washington; R. A. Millikan, director, Norman Bridge Laboratory of Physics, and chairman of the Executive Council, California Institute of Technology.

Since its establishment by an Act of Congress, approved by President Lincoln in 1863, one of the important functions of the National Academy of Sciences has been to serve as official adviser to the Government in scientific matters whenever called upon by any of its departments. Specifically, Section 5, Article 5, of the academy constitution reads: "The advice of the academy shall be at all times at the disposition of the Government upon any matter of science or art within its scope." The Act of Incorporation further states that "the academy shall receive no compensation whatever for any services to the Government of the United States."

At the time of its foundation during the Civil War, as the earlier records of the Academy indicate, its committees and its members dealt actively with military and naval problems of precisely the same type as those which insistently pressed for solution during the World War. Similarly, during the World War, the Academy offered its services to the Government and at the request of President Wilson created the National Research Council as the active agent of the Academy to assist the Government in organizing the scientific resources of the country for its need at that time.

As the work of the National Research Council progressed, it became evident that the Council might be a useful organization for peace time and the President's recognition of this led him to perpetuate it to stimulate scientific research, to survey the larger possibilities of science, to promote cooperation in research, to study military and industrial problems in connection with the war, and to gather, collate and make available the scientific and technical information of the world.

The Council is not an institution for the maintenance of scientific laboratories. It is rather an organization which, while clearly recognizing the indispensable value of individual investigations, hopes particularly to help to bring together scattered work and workers. It wishes to coordinate scientific research in America, especially, perhaps, those problems which depend for successful solution on the cooperation of several or many workers and laboratories. A feature of special significance in

the plan of organization of the National Research Council is provision for bringing together year by year outstanding research men as chairmen of the technical divisions of the Council. They are placed in a position to devote their main attention to the study of the conditions of research in their respective fields and have been a means for the encouragement of research in these fields.

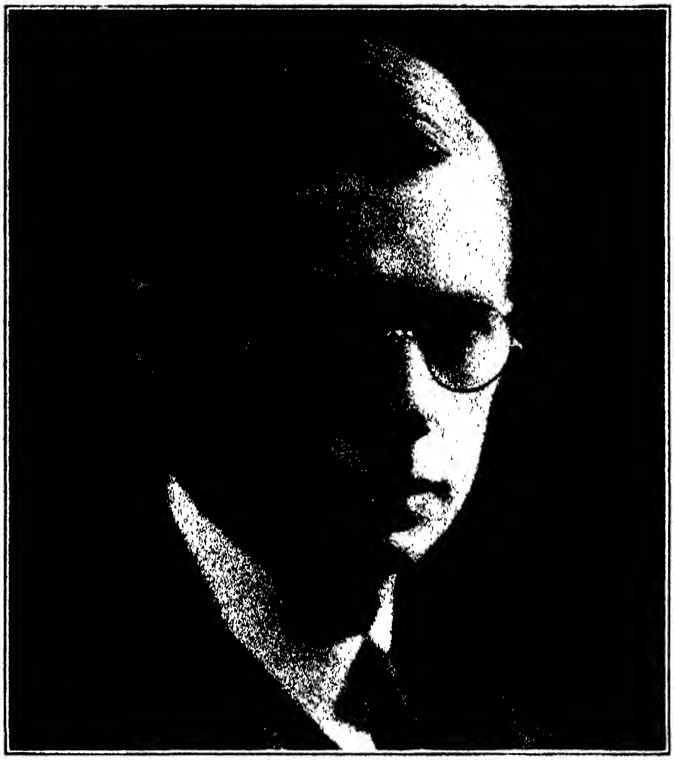
Among the various methods of contributing practical assistance to American science in harmony with the general point of view outlined above, which the Council has so far adopted, perhaps the most important is the establishment of special committees of carefully chosen experts for specific scientific subjects or problems urgently needing consideration. They plan modes of attack and undertake to find men and means (with the assistance of the general administrative offices of the Council) for carrying out the plan. Such problems may lie either in the field of pure science or in that of applied or industrial science.

The Science Advisory Board has met twice and at its recent four-day session in Washington it gave consideration to three general problems.

The first was questions of proper organization, or functioning, or program of the scientific and technical services of the Government on which the advice of the board has been specifically requested. The second was similar matters which have otherwise come before the board, and which need attention in order that essential technical services shall not be impaired by economy, or unwise projects be supported, as may easily happen when the determining issues are obscure or highly technical. The third was basic considerations of the more permanent policy of the Government toward scientific work.

President Compton, chairman of the board, states that, inasmuch as the actual problems now under consideration are pressing and of a confidential nature, no discussion of them would be appropriate at this time.

THE BUILDING OF THE NATIONAL ACADEMY OF SCIENCES



—*Bachrach*

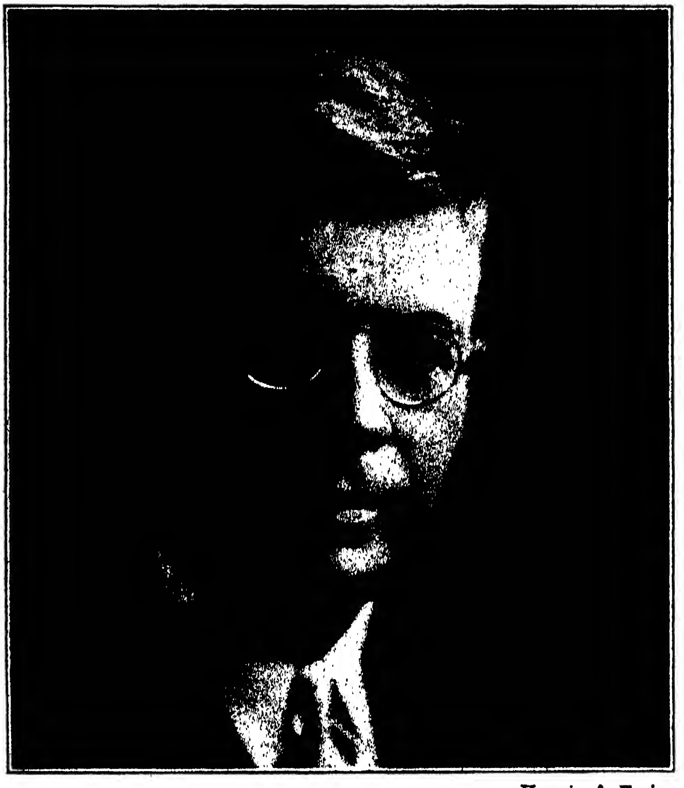
PRESIDENT JAMES BRYANT CONANT OF HARVARD UNIVERSITY

## NEWLY ELECTED UNIVERSITY PRESIDENTS

At the opening of the academic year newly elected presidents of three leading eastern universities have taken up their work. They are Dr. James Bryant Conant at Harvard University, Dr. Harold Willis Dodds at Princeton University and Dr. Harry Woodburn Chase at New York University.

Born in Dorchester, Massachusetts, in 1893, Dr. Conant entered Harvard College in 1910 and has been identified with this institution since that time as student, instructor, assistant and associate professor, Sheldon Emery professor of organic chemistry, chairman of the chemical division and now finally as president. He is only five years older than Charles William Eliot, also a professor of chemistry, when the latter assumed the presidency in 1869 at the age of thirty-five. He was granted two temporary absences from Cambridge; during the war he responded to a call from Washington to engage in chemical research and organization for the United States Government; in 1925 he devoted much of his time to studying the methods of research and instruction in German universities.

Dr. Conant has distinguished himself by his contributions to organic chemistry. His important work on photosynthesis in plants, published in 1932, earned for him the William H. Nichols medal of the American Chemical Society and the Chandler medal of Columbia University. Dr. Conant has been interested in the broader aspects of his work and some of his studies have been carried out jointly with Professor P. W. Bridgman, as well as with other members of the physics department. He has



—*Harris & Ewing*

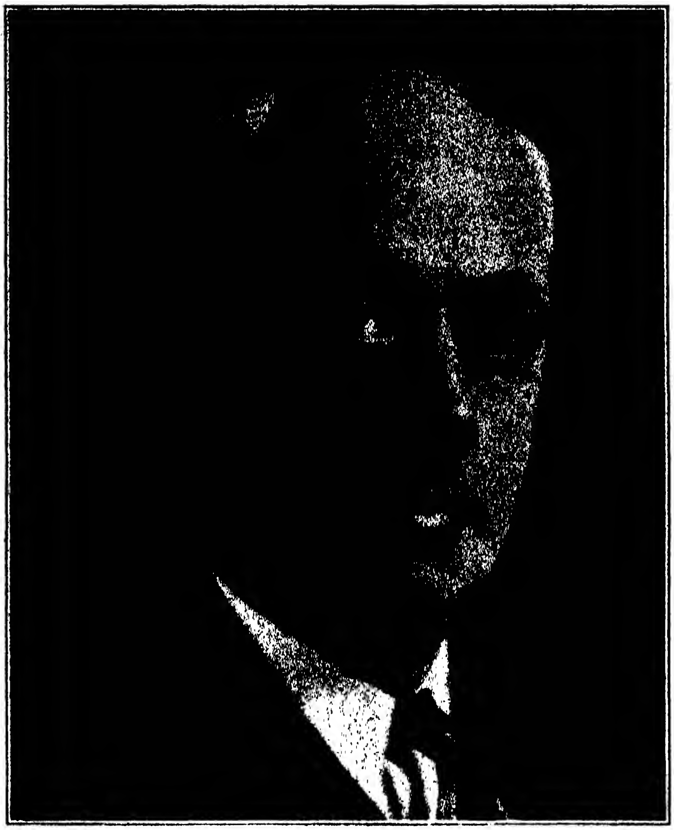
PRESIDENT HAROLD WILLIS DODDS OF PRINCETON UNIVERSITY

also received the cooperation of members of the staff of the department of physiology and of the medical school.

In 1929 Dr. Conant was elected a member of the National Academy of Sciences and the following year he was appointed a scientific director of the Rockefeller Institute.

Professor Harold Willis Dodds, who has assumed the presidency of Princeton University, is only three years older than Professor Conant. He is Princeton's fifteenth president and the youngest the university has had for 175 years. Born in Utica, Pennsylvania, he attended Grove City College, where his father, a Presbyterian minister, was Bible professor. Thirteen of the fourteen preceding presidents had been clergymen. The one previous exception was Woodrow Wilson, who also entered the chief office of the university by way of a professorship in politics. Wilson's father also was a clergyman.

Professor Dodds taught school for two years before beginning his graduate work at Princeton, where he took his master's degree in 1914. He became instructor in economics at Purdue University and later moved to Philadelphia, where the University of Pennsylvania granted him his doctor's degree in 1917. During the war-period he acted as executive secretary of the State of Pennsylvania for the U. S. Food Administration. He then served successively as member of the faculty of Western Reserve University (as assistant professor of politics), the University of Pennsylvania (as part-time lecturer), Swarthmore College (as part-time lecturer), New York University (as part-time lec-



CHANCELLOR HARRY WOODBURN CHASE OF NEW YORK UNIVERSITY

turer) and Princeton University, where he was professor of politics. He devoted most of his time to the National Municipal League from 1920 to 1928 when he served as executive secretary and editor of its journal, *The National Municipal Review*. He retained the latter position until this year.

In 1922, on the recommendation of Secretary Charles Evans Hughes, Professor Dodds was appointed as electoral adviser to the government of Nicaragua. His first duty was to formulate an electoral law for the country which, little altered, is still known to its citizens as the "Dodds Law." Two years later President Diaz called upon him to supervise registration for the presidential election in Nicaragua, which then enjoyed one of the most peaceful election days in its history. Professor Dodds rendered further service to Latin-American countries by serving as technical adviser in 1925 to the Tacna-Arica Plebiscitary Commission headed by General John J. Pershing.

Dr. Harry Woodburn Chase, former president of the University of Illinois and of the University of North Carolina, became the eighth chancellor of New York University on July 1, when he succeeded Dr. Elmer Ellsworth Brown.

During the past fourteen years, Chancellor Chase has become an outstanding university administrator. Under his leadership the University of North Carolina attained its position as one of the most progressive institutions of higher learning in the South. As president of the University of Illinois for the past

three years, he pushed forward plans for the promotion of the university's service to the state in the face of a decreasing budget.

Dr. Chase was born at Groveland, Massachusetts, fifty years ago. He was graduated from Dartmouth College and in 1908 received his master's degree from this institution. He obtained his Ph.D. from Clark University, where for a short time he was director of the clinic for sub-normal children. In 1910 he joined the faculty of the University of North Carolina as professor of the philosophy of education under the late Dr. Edward Kidder Graham.

Upon the death of Dr. Graham in 1918, Dr. Chase, then a professor of psychology, became in quick succession acting dean, chairman of the faculty and acting president of the university. While the Board of Regents was casting about to find a president to carry out the reorganization program that Dr. Graham had planned for the institution at Chapel Hill, Dr. Chase was so proving his success as an administrator that in 1920 he was selected by the Board of Regents as the best man for the post.

In 1930 Dr. Chase accepted the presidency of the University of Illinois, and it was this position he left to fill the chancellorship of New York University.

WILLIAM BEAUMONT

THE FIRST REPRODUCTION OF AN OLD DAGUERREOTYPE LOANED BY DR. HARRIS A. HOUGHTON, OF THE NEW YORK ACADEMY OF MEDICINE.

## IN HONOR OF WILLIAM BEAUMONT

EARLY in October the New York Academy of Medicine was the scene of the celebration of the one hundredth anniversary of the publication of William Beaumont's "Experiments and Observations on the Gastric Juice and the Physiology of Digestion." In commenting upon the book, Professor Walter B. Cannon, of Harvard University, said:

In the period between 1833 and 1933 thousands of other books had been written and published, had had their brief day and ceased to be. What was there in Beaumont's writing that endowed it with vitality and permanent value? It possessed those qualities because it

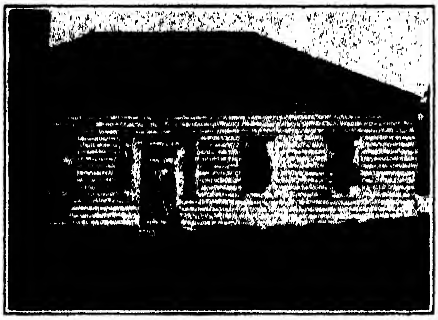
embodied the simple, straightforward report of a scrupulously honest man who used his senses cautiously in a significant scientific inquiry, who recorded exactly how he used them and what they revealed, and who drew limited inferences from the observed facts. He had, to be sure, an unusual condition to study and describe . . . a human being with a direct opening into the stomach on the left side of the body, through which instruments and food could be introduced and through which also the gastric contents and the digestive juice could be extracted. . . .

The conditions which surrounded him were in many respects highly unfavorable both to the prosecution of research and to the securing of satisfactory results. It was at a frontier army post on the Island of Machilimacinac, near the union of Lake Michigan and Lake Huron, that the young Canadian hunter, Alexis St. Martin, received the gun shot which fractured ribs and made openings into the cavities of the chest and abdomen. Portions of the lungs and stomach, much lacerated and burnt, protruded through the openings, making, according to the record, "an appalling and hopeless case." The life of the wounded man was despaired of, but, by careful attention and treatment, and, no doubt in part because of his own youthful vigor, he recovered, in about ten months, sufficiently to promise ultimate survival. Even at that time, however, he was "altogether miserable and helpless," and since no one else would look after his needs, Beaumont took him into his own home and "medically and surgically treated and sustained him, at much inconvenience and expense, for nearly two years, dressing his wounds daily, and for a considerable part of the time twice a day, nursed him, fed him, clothed him, lodged him and furnished him with such necessities and comforts as his conditions and sufferings required."

The unique contract between William Beaumont and St. Martin was described by Dr. Harris A. Houghton, chairman of the celebration. The second part of it is quoted here.

And the said Alexis, for the consideration hereinafter mentioned, further especially covenants and agrees with said William, that he, the said Alexis, will at all times during said term, when thereto directed or required by said William, submit to, assist and promote by all means in his power, such Physiological or Medical experiments, as the said William shall direct or cause to be made on or in the stomach of him, the said Alexis, either through or by the means of, the aperture or opening thereto in the side of him, the said Alexis, or otherwise, and will obey, suffer and comply with all reasonable and proper orders or experiments of the said William, in relation thereto, and in relation to the exhibiting and showing of his said stomach, and the powers and properties thereof, and of the appurtenances and powers, properties, situation and state of the contents thereof. It being intended and understood both by said William and said Alexis that the facilities and means afforded by the wounds of the said Alexis in his side and stomach shall be reasonably and properly used and exhibited at all times upon the request or direction of said William for the purpose of science and scientific improvements,

FORT MICHILIMACKINAC IN MIDWINTER
SHOWING ONE OF THE BLOCK-HOUSES, WITH THE SURGEON'S QUARTERS AND HOSPITAL TO THE LEFT OF IT.



THE ONE-STORY FRAME HOSPITAL AT THE OLD FORT

TO WHICH ALEXIS WAS REMOVED, AND WHERE HE LAY DURING HIS LONG CONVALESCENCE.

**the furtherance of knowledge in regard to the power, properties and capacity of the human Stomach.**

Dr. Bernard Sachs, president of the academy, opened the meeting with a brief address, in which he related the salient points in Beaumont's unusual career. William Beaumont as an army officer was the subject of an address by Major General Robert U. Patterson.

An exhibition of books and other memorabilia relating to the life, work and travels of Beaumont will be on view at the New York Academy of Medicine until November 3.

## AN ELECTRICAL SURVEY OF ISLANDS AND CONTINENTS IN INVISIBLE FILMS ON THE SURFACE OF WATER

SURFACES, or more properly interfaces, are almost all important in a study of the action of the muscles, nerves, blood and all the other parts or materials of the human body. In a research begun several years ago as supported by the Julius Stieglitz Fund of the Chemical Foundation, William D. Harkins and E. K. Fischer have begun a study of the fundamental characteristics of membranes, especially of the electrical relations. As a part of this work the earlier methods have been modified in such a way as to enable them to give fundamental information concerning the forces which hold molecules together, the orientation of molecules in thin films, and the structure of the different regions of a film.

The surfaces of all natural and artificial bodies of water are covered, more or less, by exceedingly thin invisible or sub-ultra-microscopic films of oily substances. These invisible films are very much thinner than those often seen, which are visible layers of oil, highly colored by interference of the light waves which traverse them, and are about 1/25,000 of an inch in thickness. It has been known for many years that electrical methods may be utilized in the study of such films, but the results obtained were not only disappointing but conflicting. About five years ago Professor Harkins suggested that the discord in the results might disappear if both electrical measurements and measurements of the lateral pressure of the film were made simultaneously.

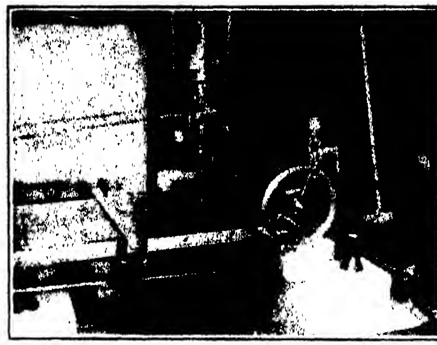
It is a remarkable fact that an oil film only one molecule thick, that is, with a thickness of only about one tenth of a millionth of an inch, is capable of transmitting a lateral pressure which is large enough to move a floating sheet of metal, and to do this over a considerable number of inches. Such a film may exhibit many of the characteristics of a solid, and is then called a monomolecular or unimolecular solid film, or it may act in the two dimensions of the surface as a liquid or as a gaseous film. The Hardy-Harkins-Langmuir theory of surfaces indicates that with films produced from oils, such as oleic or stearic acid, the molecules are oriented, as are the soldiers in a troop on parade. This orientation is most manifest when the molecules are tightly pressed together to form a condensed

film, since in this case very few molecules get a chance to "lie down on the surface." In gaseous films this orientation is partly but not wholly preserved.

In the oil film the water-like heads of the molecules turn downward toward the surface of the water, while the oil-like tails of the molecules project upward. The electrical tests indicate that the heads of the molecules are negatively charged with respect to the more positive tails.

One of the three cells of the storage battery used in an automobile gives a potential of about two volts. It is somewhat remarkable that the presence of a film of oil one molecule (0.0000001 inch) thick may change the potential difference at the surface by as much as about one half a volt.

The greatest practical use of the apparatus used in the electrical testing of a surface is to make a topographic survey of a water surface. The surface potential is found to rise rapidly as the electrode, held a few millimeters above the surface, approaches the edge of an invisible island or a continent of closely packed molecules of the oil; the potential remains high while the electrode is over the island, and falls again as the ocean of gaseous film is approached. Thus, what is invisible to the eye and to the microscope is revealed by the movement of the needle of the electrometer which is used to detect the change of potential. This motion is in turn shown by the movement of a beam of light.



APPARATUS FOR FINDING ISLANDS OF INVISIBLE FILM ON WATER

Certain large molecules, about 60 times larger than the rather large molecules usually used to produce films, have exhibited the relation that they form films of only one fourth the thickness of those produced by the smaller molecules. Therefore, these large molecules, which give a film only one fiftieth of a millionth of an inch in thickness, must lie flat on the surface.

## RECENT DEVELOPMENTS IN THE STUDY OF CHEMICAL EFFECTS OF ALPHA PARTICLES AND ELECTRONS

WHEN alpha rays from radon or other radioactive elements pass through the molecules of substances, they ionize them by removing electrons temporarily. Chemical action frequently results and has been found to be dependent on and proportional to the number of ions formed, though the proportionality factor is not the same as in Faraday's laws of electrolysis.

Similarly, if gas ions are produced in gases by electrical discharge, chemical action similar to that in radon is produced, in the bosom of the gas, however, not at the electrode. In different substances under parallel conditions of discharge the amount of reaction bears the same relations as in the same reactions under alpha radiation. This leads to the assumption that the number of molecules reacting per ion is the same in both cases, though one is not able to measure nor calculate the ionization in electrical discharge.

Such studies have now been extended to perhaps a hundred different reactions under alpha radiation and to many more in electrical discharge. Recent investi-

gations carried out either in the laboratory of Professor Mund, at the University of Louvain in Belgium, or in the School of Chemistry under the directorship of Professor S. C. Lind, at the University of Minnesota, which are the two centers where radium is being devoted to this purpose, include the following reactions: The synthesis and decomposition of hydrogen iodide, hydrogen bromide, hydrogen chloride, hydrogen sulfide and of ammonia, the synthesis of water at high and low temperatures (−180 to +500° C.) and the polymerization of gaseous derivatives of acetylene.

Much of recent research is directed toward the mechanism of the reactions, whether the gas ions are themselves the activated agents that react directly or whether they first give free radicals and free atoms that enter into reactions. There is much indirect evidence for both views with no possibility of a convincing decision in sight.

The influence of foreign non-reactive gases is important. They are also ionized by the alpha particles and their ions contribute as much to the reaction as ions of the reactant, even when the foreign gas consists of single inert atoms like the inert gases. This indicates strongly that the reaction is a clustering process about the positive ion of the inert gas or that by an exchange of ionization on collision the inert gas ions ionize and activate the reactant. This is impossible, however, when the ionization potential of the inert gas, like xenon, is lower than that of the reactant gas, like acetylene. And yet, xenon ions do cause acetylene molecules to polymerize with high efficiency. This argument is almost, but not quite, conclusive that the ions themselves are the reactive agents.

All foreign ions are not equally efficient in promoting a given reaction. While many of them are 100 per cent. efficient, carbon dioxide is only 14 per cent. efficient in its own synthesis from carbon monoxide and oxygen, while water vapor is 100 per cent. efficient in its synthesis from hydrogen and oxygen —two reactions which under alpha radiation are entirely similar, except in this one respect, even having identical yields per ion.

The factor on which the efficiency of foreign ions depends is not definitely known, but Mund has presented recent evidence that it may depend on the dielectric constant of the gas concerned.

THE SCIENTIFIC MONTHLY

DECEMBER, 1933

# TREE GROWTH AND CLIMATIC CYCLES

By Professor A. E. DOUGLASS

DIRECTOR, STEWARD OBSERVATORY, UNIVERSITY OF ARIZONA, RESEARCH ASSOCIATE, CARNEGIE INSTITUTION OF WASHINGTON

THIS paper discusses certain variations in the width of the annual rings of trees that suggest, through climate, a relationship to the sunspot cycle. Since tree rings form the vehicle in which the variations are found, some reference to them is necessary by way of introduction.

The total number of rings carefully examined as to growth date is well over half a million. They are grouped in some 5,000 specimens, mostly different trees. About 250,000 rings have been measured with care after accurate dating in all cases, except, of course, the geological rings. The collection and measurement of some fifty giant sequoia sequences, together with general climatic studies, received the generous assistance of the Carnegie Institution. The collection of specimens and dating of prehistoric ruins in Arizona and New Mexico back as far as 919 A. D. was most helpfully financed by the National Geographic Society. The Research Corporation of New York, the American Museum of Natural History, the Museum of Northern Arizona and a number of friends have each made important and valued contributions. The University of Arizona has given a substantial portion of my time.

The discovery in 1911 that dates of individual growth rings may be recognized accurately in tree after tree over wide areas has resulted in the building of a 1,200-year tree ring chronology in Arizona and New Mexico, and has placed the interpretation of tree growth on a climatic basis. The development in 1913 of a method of cycle analysis of greatly increased efficiency gave a completely new approach to the type of cycle here involved, that is, the apparently discontinuous cycle. This method recognized the value of the "residual" method of plotting cycles and the rapid and flexible graphic correlations possible in the automatic cyclogram. The cycles here quoted as found in tree ring records have been picked out in the original data from a considerable range of cycle values and are not the result of tests of selected values, for a special feature of the cyclogram is the wide range of cycles visible at once. Each cycle is first recognized in its extended form, of which integrations, such as shown in this paper (Fig. 11), may be made if desired.

Any relationship between cycles in tree rings and cycles in the sun must almost certainly take place through the medium of the weather, which influences tree growth and in turn is energized by solar radiation. Hence the relationship between tree growth and weather is of primary importance.

The theoretical basis for the climatic interpretation of tree growth may be expressed as follows: If many widely separated trees in a uniform area show the same variations in the same years con-

tinuously (that is, for hundreds of years), then these variations are climatic in nature, for climate is the common continuous factor in the life of the forest trees.

A second principle of interpretation brings us a little closer to the dominant meteorological element in the trees, namely, that a forest limit may isolate the climatic factor involved. Thus, for example, the lower pine forest border in Arizona, which separates the successful forest from the desert below, is a matter of altitude and therefore water supply, which in that region depends on altitude. The trees near this forest limit therefore give prominence to a rainfall record, though other factors are there. This is shown in Fig. 9 in which agreement is shown between tree growth and rainfall at Prescott, near the lower forest border of the Arizona pines. The lower pair include some conservation and have to each other a correlation coefficient of 72 per cent.

Fig. 10 gives us a similar comparison for Southern California areas. In the upper set, three curves are compared in their original values; in the lower set the smoothed values are shown. The first curve gives Lynch's Rainfall Indices, 1770 to 1930, for the Los Angeles area, including San Diego records after 1850. The second curve is from sixteen pines in the San Bernardino Mountains at about 6,000 feet elevation, in the large Santa Ana Valley northeast of Redlands and lying just east of the rainfall area considered. Here the resemblance to rainfall is quite evident, especially in the minima. The correlation coefficient between these two curves from 1770 to 1930 is 45 per cent. and 5 per cent. probable error, a correlation that is certainly not accidental.

The third curve ties in the sequoias, even though the correspondence is not so marked. It represents the average of four large trees that grew near General Grant National Park on steep upland slopes, thus avoiding the water conservation of the swampy basins. The distance between rainfall area and tree area is 200 miles. The correlation coefficient here is 28 per cent. and 5 per cent. probable error for values since 1770. This correlation was examined by Dr. Dinsmore Alter and considered very probably real. This is less than the former, as expected from the greater distance. These correlations were computed by Dr. W. S. Glock. This comparison just obtained confirms the estimate previously made that water supply, while less vital than in the Arizona pines, is still an important factor in the sequoias. The accuracy of sequoia dating was carefully checked again in 1931.

Thus the tree growth cycles shown later may be safely taken as having a strong climatic significance, with rainfall as the probable major element.

### I. The Hellmann Cycle

Many tree groups show, since 1850, an 11-year cycle with two crests. This cycle in actual length varies from 11.2 to 11.8 years, with perhaps the commonest value at 11.4. This compares favorably with 11.35 years, which is the average sunspot cycle length since the maximum of 1837. The two crests usually are somewhat unequal in height and in spacing and in stability. In most cases one crest comes near sunspot maximum and the other near sunspot minimum. The one at maximum is much more stable than the one at minimum.

A cycle that fits this description was found by Hellmann in 1906 in North German rainfall. It is shown in Fig. 11a. Though Hellmann had little confidence in this relation to the solar cycle it seems to be sufficiently frequent in trees to justify using his name. In the figures the sunspot minimum is inverted and turned into a second maximum and carefully marked in every case. By this slight modification the eye is better able

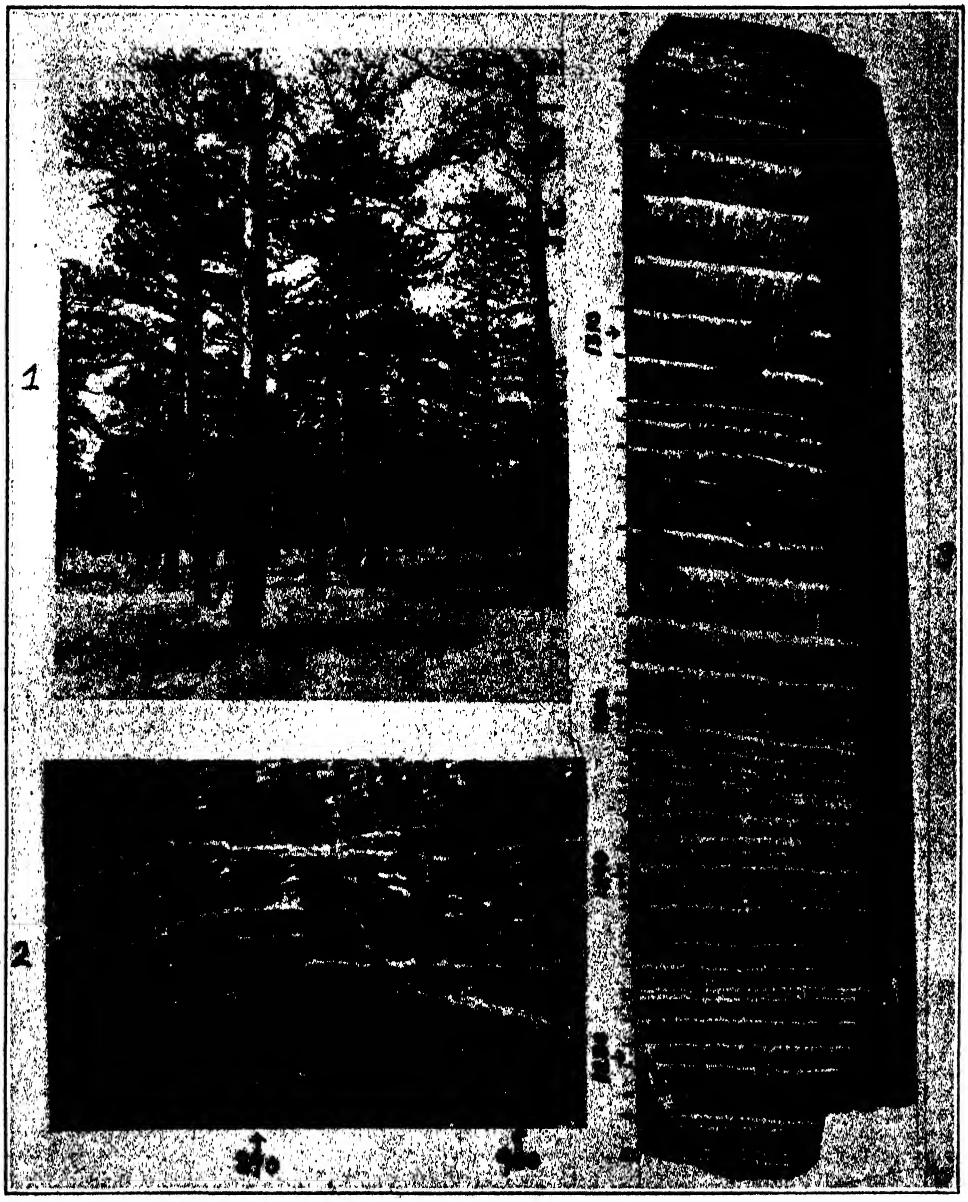


PLATE 1: 1. NORTHERN ARIZONA PINE FOREST; PHOTOGRAPH BY U. S. FOREST SERVICE. 2. FINGER PRINT OR IDIOGRAM A. D. 890–9, A CONFIGURATION OF RINGS EXTENSIVELY USED IN CROSS-DATING. 3. THE GREAT DROUGHT, 1276 TO 1299, AS SHOWN IN CHARCOAL FROM SHOWLOW, ARIZONA; BEST ARIZONA RECORD OF DROUGHT YET FOUND; NOTE THE FAVORABLE CONDITIONS FOLLOWING THE DROUGHT.

to catch uniformity or variation in the Hellmann cycle.

The existence of this cycle and the others mentioned below is based on the cyclogram patterns in Fig. 8, in which the letters correspond to the letters in Fig. 11. The cyclogram has two important characters. It is first a plot of the differences between an exactly repeating period and the observed maxima, and so cycles become separated, since they appear as lines pointing in different directions, and second, it is not merely a plot of selected maxima, it is an automatic plot of the entire data, usually smoothed by Hann's formula. Hence it is not a plot of points here and there, it is a multiple reproduction of the data in such form that correlations become at once apparent as a new feature. Such are the horizontal alignments shown in the various patterns of Fig. 8, which correspond to a cycle length of 11.4 years. The patterns carry two examples of this alignment, one above the other, as may be seen. A two-crested sunspot cycle, such as the Hellmann cycle, produces double that number of horizontal lines. For example, the last pattern, l, is taken directly from the sunspot cycle itself with the minima inverted. Such inversion turns it into the Hellmann form. Thus the existence of a Hellmann cycle in any pattern may be judged by its similarity to l.

In Fig. 8a Hellmann's curve of German rainfall is extended to 1920 by the Berlin rainfall record.

In 1912–13 eighty North European trees were sampled. Several hundred dates of maximum growth between 1850 and 1907 are collected in Fig. 11b (and 8b), which gives the result of this single qualitative test in a symmetrical Hellmann cycle. The only difference from Hellmann's curve is in the greater relative height of the crest at maximum. This curve has been reproduced in extended form in Vol. I, "Climatic Cycles and Tree Growth," page 78. The correlation coefficient between full curve and the sunspot numbers is $+.57 \pm .07$.

Fig. 11c represents a group of twelve trees from Dalarne, Sweden. The mean curve of the twelve, between 1830 and 1907, based on 900 measures, places the larger maximum directly over the sunspot maximum. The minimum crest nearly disappears. The extended curve was reproduced in Vol. I, just mentioned, page 75. Its correlation coefficient with the sunspot numbers is $+.62 \pm .06$.

In an interesting group of thirteen trees from Eberswalde, Germany, 1,100 measures, between 1825 and 1907, the minimum crest has practically gone, except in a very few cases, leaving a massive crest at sunspot maximum. This is shown in Fig. 11d. The extended curve has been reproduced in the same volume, page 75. Its correlation coefficient with the sunspot numbers is $+.51 \pm .07$.

Six groups, 57 trees, of the nine North Europe groups collected in 1912 show in their cycle average between 1830 and 1910 a good replica of the mean sunspot cycle, as can be seen in Fig. 11e. This includes about 4,500 measures. The minimum crest occurs rarely and disappears in the average. The extended curve has been reproduced in the same volume, page 77. Its correlation coefficient with the sunspot numbers is $+.56 \pm .05$.

Now we consider tree groups in the United States. A Vermont curve from eleven trees and some 600 measures, 1852 to 1911, shows a strong 11-year cycle with one crest much more prominent than the other, and two or three years phase displacement. The range of variation is about 28 per cent. of the mean value. The correlation coefficient is $+.53 \pm .06$, after allowing for lag of $-3$ years. Seventeen Douglas firs on the Oregon coast, 900 rings measured, 1854 to 1910, reach a single crested cycle with a range of about 10 per cent. There is also a slight lag. The corre-


PLATE 2: 4. GENERAL GRANT TREE, CALIFORNIA; PHOTOGRAPH BY THE AUTHOR. 5. COMPLACENT SEQUOIA RINGS IN WELL-WATERED BASINS. D–8, REDWOOD BASIN. 6. SENSITIVE SEQUOIA RINGS ON STEEP UPLAND SLOPES. D–5 IN SAME REGION. 7. EBERSWALDE SECTION WITH SUNSPOT MAXIMA MARKED; THE LAST IS 1905; 1894 IS DISTORTED BY A PEST EFFECT (PUBLISHED IN "CLIMATIC CYCLES AND TREE GROWTH," CARNEGIE INSTITUTION, 1919, PLATE 8A). 8. CYCLOGRAMS OF ORIGINAL DATA SHOWING HELLMANN OR SUNSPOT CYCLE CONTINUING THROUGH THE DATA; A AND F ARE RAINFALL RECORDS; OTHERS ARE TREE RECORDS; L IS SUNSPOT CYCLE WITH INVERTED MINIMA FOR COMPARISON; SEE TEXT, AND NOTE AT END.

lation coefficient is $+.45 \pm .07$, after allowing for a lag of $-2$ years.

The largest American groups come from California and Arizona. These are perhaps best introduced by curves from the Southern California rainfall, using "Lynch's Rainfall Indices," as shown in Fig. 11f, extending back to 1770, a very important and useful compilation verified by the San Bernardino Mountain tree record. These indices since 1850, of course, became actual rainfall records. Smoothed curves of this rainfall have an obvious resemblance to the Hellmann cycle. Cyclogram analysis, 1855–1901, showed interference by a double-crested 14-year cycle and a short variation, apparently a little more or less than two years, which causes an apparent scattering of yearly values. Without these the Hellmann cycle becomes an excellent cycle with more than 30 per cent. range. A study is now being made of this two-year cycle to see if it can be distinguished from accident.

Fig. 11g shows the Hellmann cycle in the sequoias. This comes from the tabulated means of eleven trees, about 600 measures, published by the Carnegie Institution in 1919. The data originally covering 1810 to 1914 have been extended to 1930 by collections in the Sequoia National Park. The trees are complacent and the range is small, namely, about 8 per cent., but the maxima are clean cut and the crests are very stable as there is little interference from longer cycles. A cyclogram study of this sequoia record extended back to 1804 is shown enlarged in Fig. 8m.

Fig. 11h shows the Hellmann cycle in the southernmost sequoia grove, south of Sequoia National Park and near Springville, where three 3,000-year trees have been found. This curve is made from 500 measures covering 1805 to 1890. The topographic conditions are good but not the very best obtainable for a climatic record, since the area is rather flat and the ground sometimes moist. After removing by mathematical methods a 19-year cycle, the Hellmann cycle is evident with a range of 15 per cent.

Fig. 11i shows the Hellmann cycle in the San Bernardino pines, derived from 800 ring values, about 1850 to 1900; Fig. 8i uses the larger interval, 1825 to 1925. These trees grew at about 6,000 feet elevation in Santa Ana Valley, northeast of Redlands. Collection and measurement of this group was made with the generous help of Mr. J. J. Prendergast, president of Bear Valley Mutual Water Co. Here a 14-year cycle was strong. On subtracting it from the data the Hellmann cycle shows a range of 16 per cent., and probably more.

The Hellmann curve in the Arizona pines is given in Fig. 11j. This is derived from 3,000 measures in 58 trees, distributed across two hundred miles of country, approximately including 1850 to 1905; the cyclogram, Fig. 8j, uses the interval 1825 to 1920. A 19-year cycle lasting since 1800 completely dominates the record. This was removed by mathematical methods and also a 14-year cycle, whereupon the Hellmann cycle was well marked in the curve. It shows a lag of two or three years in relation to sunspot phase. It should be added that some of the individual groups in this large assemblage of trees, such as the one from the Grand Canyon, give the Hellmann cycle in prominent form without the interfering cycles.

Fig. 8k shows Grand Canyon tree growth from seven trees, 1825 to 1920. The effect is here shown of using the center of gravity of the maxima. It produces a Hellmann cycle of very good form. There is the same probable two or three year lag, as in the general Arizona curve. A lag of $-3$ or $-4$ years fits many of the curves very well.

Fig. 8l, as already mentioned, gives the sunspot numbers with an inversion of minimum values for comparison with the Hellmann cycles from terrestrial

sources. For method of reading the cyclograms, see note at end of paper.

This concludes the presentation of the Hellmann cycle in trees. At this point two notes should be made. First, this cycle is common in trees since 1850 and, second, the interfering cycles, 14 and 19 years, are widely distributed cycles. The shorter one is plainly a solar cycle, as will appear later, and the longer is probably so.

### II. Historical Changes in Hellmann Cycle

Having described a cycle in tree growth that has the same length as the sunspot cycle, but usually of different shape, it is well to see if any historic changes in this cycle can assist us in deciding on its identity. In 1909, two years before exact dating was developed, a trace of Hellmann cycle was noted in the Arizona pines. In the next three years a remarkable example of Hellmann cycle was found on the wood in rings 1430 to 1530 or later. The two-crested form was noted, lasting with some interference to near 1650. There it stopped, but was resumed again later. This is shown in Fig. 12. An 11-year cycle reappeared after 1725, but it did not resume the regular Hellmann type till after 1800. Even then it was partially hidden by interfering cycles. The complete failure of the 11-year cycle during the interval from 1660 to 1725 caused at the time much doubt of any significance in the apparent relationship to the solar cycle. All this was published in 1919, with full reference to the failure near 1700. In 1922 Maunder published an article on the great dearth of sunspots from 1645 to 1715, and gave me my first information regarding that phenomenon. During the dearth, sunspots were very rare; two intervals of 10 years and four or five of 5 years show no sunspot records at all. Under such conditions it is quite evident that estimates of sunspot minima have no value and dates of maxima are none too good, for very large spots may come at almost any time in the cycle. This coincidence between the failure of spots and the failure of the 11-year cycle in trees was a source of great interest to Dr. Maunder and myself and greatly strengthened the solar explanation of the Hellmann cycle in trees.

On the occasion of publishing some account of this in 1928, it seemed worth while to find what cycles, if any, replaced the 11-year cycle in tree growth. The Arizona trees answered at once with a 10-year cycle. Four sequoias, which generally seemed to show more 11-year cycles than the others, gave a plain 10-year cycle during the dearth of sunspots. Many sequoias showed cycles also at 8.5 and about 14 years. A long hemlock record in Vermont gave 20 and 28 years with probable half values at 10 and 14.

So it seemed necessary to examine the sunspot record with more care, to find how it compared with these results. The maxima assigned by Wolfer were plotted and analyzed, and it was evident that a 10-year cycle between 1615 and 1788 would fit as well as the usually accepted 11-year cycle. On trying it out the average residual is just about the same. But if one uses Wolfer's weights, as of course one should, the average residual decreases 25 per cent., thus giving some preference to the 10-year cycle and producing agreement with the tree records.

All this is exceedingly difficult to show in the form of a plot or diagram, because with the exception of the cyclogram method, used since 1913 in these studies, there is no adequate way of representing the mixtures, the changes, the continuities or the interruptions of cycles in a single plot. I am therefore showing in Fig. 13 a certain form of plot specially adapted to presenting cycles. It gives on ordinary rectangular coordinates the residuals between an exact

cycle and the observed cycle. If the residuals are constant the plotted points form a horizontal line. If in any part of the diagram the residuals are changing at constant rate, they must form a straight slanting line. But any set of residuals changing at constant rate is merely expressing a cycle of different length. Thus the direction taken by any row of plotted points becomes a measure of cycle length. This is the important feature and to such a plot the name of cyclogram is given. So in Fig. 13 in plots 1 and 2 the horizontal alignment in the right half, mostly since 1800, represents the 11-year sunspot cycle. Before 1800 the line is on a slant pointing (if it were on a clock dial) toward 2 o'clock. This indicates a 10-year cycle. The 1 o'clock line is an 8½-year cycle. The 5 o'clock line is a 14-year cycle.

The uppermost of the four plots produces a characteristic Hellmann effect by including sunspot minima as well as maxima (See also Fig. 8 *l*). The 10-year cycle effect in the left half is more conspicuous than in the second line giving sunspot maxima only. The second plot shows the alternative possibilities of 10 and 11-year cycles in the maxima. Plot 3 gives the obvious 10-year effect in Arizona pines from 1600 to 1800. And the fourth shows a similar plot of the eleven sequoias, whose measures were published in 1919. Here the 10-year cycle is faint, but 8½ and 14-year cycles are very clear. While these cycle values appeared during the dearth of sunspots, they appear at other times also and can not be considered as specially characteristic of that solar condition. The characteristic of that time is the absence of the 11-year cycle in tree records that show it before and after.

Fig. 14 presents the same facts in a less elegant but better known form. Here the tree record indicated by a solid line begins two hundred years before the sunspot record indicated by a dotted line. The Hellmann cycle shows strongly in those two centuries. This is followed by a 10-year cycle in tree and sun during the dearth interval. In the last hundred years the agreement is resumed on the 11.4-year basis. Thus in the dominant cycles, 10 and 11 years, the trees change with the sun. The minor cycles, 8½ and 14 years, are generally present in each. The presence of these cycles in the sun is shown independently by the cyclogram process, and by Schuster's periodogram, as will appear in the next part of this paper.

In summarizing this section upon historical changes in the Hellmann cycle two items should be noted. First, after having traced the Hellmann cycle through the 1400's and 1500's, into the 1600's when sunspots were well seen, we find that it disappeared when there was a great dearth of sunspots, and reappeared when the spots came back. During the dearth there existed in the trees three solar cycles, of which the 10-year cycle was prominent in the trees and probably in the sun. This historical agreement between trees and sun offers the second definite argument that solar changes do influence tree growth.

The second note is this: To change these residual plots into the best cyclogram form as used for years, it is only necessary to add one or more duplicates of the plotted points at proper spacing below. It then became possible to trace alignments of residuals over much greater range and several differing cycles can be seen at once in the form of lines pointing different ways, and beginnings and endings may be determined as well as variations, discontinuities and change of phase. In full cyclogram analysis this diagram is produced automatically and can be varied in continuous progression over a wide range of cycle lengths. It should be carefully realized that cyclogram treatment does not exclude mathematical treatment, it precedes it; that is, it tells where the mathematical study is best applied.[1]

[1] The inadequacy of harmonic analysis may be illustrated in this way. Suppose we have a

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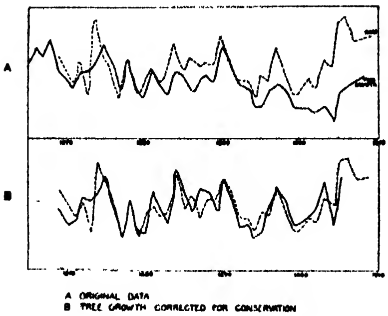


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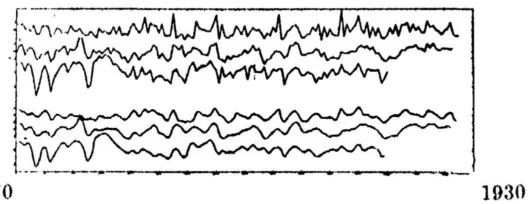


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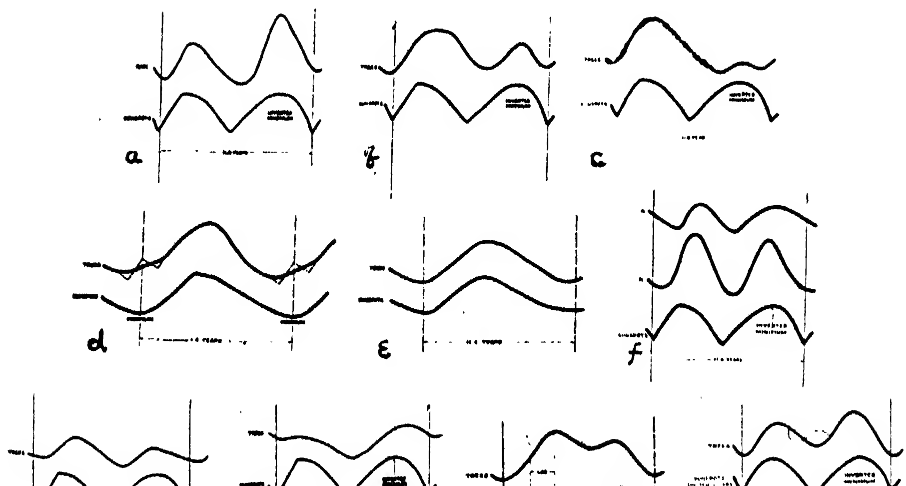



PLATE 3: 9. PRESCOTT TREE GROWTH AND RAINFALL, REGION OF LOWER FOREST LIMIT. (PUBLISHED *ibid.* PG. 68.) 10. UPPER THREE CURVES SHOW LYNCH'S RAINFALL INDICES, 1770–1930; SAN BERNARDINO MOUNTAIN PINE RECORD AND UPLAND SEQUOIA RECORD: LOWER CURVES ARE THE SAME SMOOTHED. 11. HELLMANN CYCLES OBTAINED BY INTEGRATION OF DATA USED IN FIGURE 8; SEE TEXT; CORRESPONDING SUNSPOT PHASE IS SHOWN IN LOWER CURVE.

### III. Cycles in Past Climates

A third group of results gives added weight to the probabilities of a solar relationship brought out in the last topic. It deals with the more general question: What groups of cycles are found in tree records, and are they related in any way to solar cycles?

Forty-two groups of western pine, 305 trees with 52,000 measures, have given us by analysis a large number of cycles (published in 1928). Each analysis was checked by independent tests on inverted curves and altered time scales. It was noted as early as 1926 that the cycles were distinctly grouped about values that bore simple ratios to the 11-year sunspot cycle. This was published in 1928 (January) and the more finished results appeared in 1929 in "Conferences on Cycles," issued by the Carnegie Institution. In the month of the first publication, C. E. P. Brooks published a result of similar nature derived from the Nile Gauge Readings. Clayton, a little later, noted the unexpected great relative importance of simple fractions of the 11-year solar cycle, and Abbot has dealt with radiation varying in short-cycle lengths, similarly connected with the solar cycle.

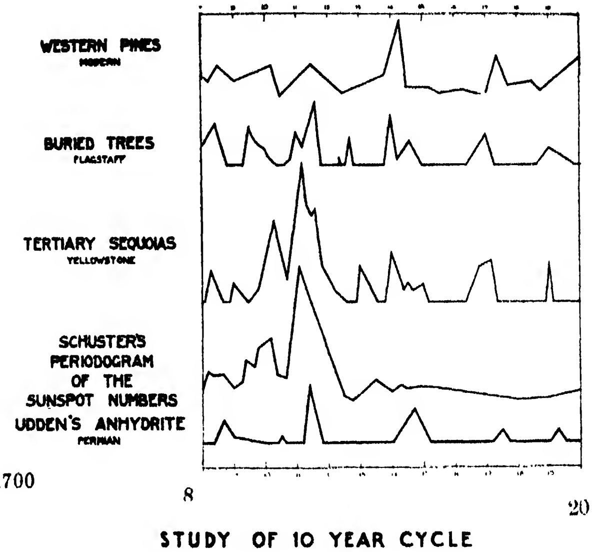
Cycles obtained in modern tree ring records are indicated in Fig. 15, upper line. They are 8½, 10, 11.4, 13.5, to 14.5, 17 and 19 and others still longer.

At Flagstaff, Arizona, in 1904 the writer discovered in an arroyo a tree stump in place that had been buried 16 feet below the top of the valley terrace. In 1919 and for several years after, with especial help from Major L. F. Brady, a large number of tree sections were secured from different depths between 1½ feet and 16 feet. The annual rings in the logs at shallow depth were of the sort now growing in the pines thereabouts—dry climate rings. The rings at 12 and 16 feet in depth were wet climate rings, large and showing a slow surge in size characteristic of continuous water supply. This contrast occurring in one locality appeared to indicate a climatic change. Ten of these buried trees, chiefly from the upper levels, gave excellent measured records aggregating more than 1,400 years. Here again we found cycle values near 8½, 9.6, 14, 17 and 19, and especially the Hellmann double-crested cycle averaging 11.4 years (see Fig. 15, second line).

The very remarkable clay records revealed by Professor Gerard DeGeer in Sweden and Dr. E. Antevs in North America well deserve careful analysis for cycles. Antevs' measures of the clay layers in the Connecticut Valley, left in the retreat of the New England ice sheet, received a brief preliminary analysis soon after they were published and a recent fairly complete review. His sequence, examined for cycles, covers about 4,000 years with a break in it. Careful cross-dating has no doubt given the separate parts a fine continuity. Cycles were frequently recognized between 7 and 8 years in length, shown in the third curve of Fig. 16. At 8.8 and at 10 there were strong cycles. The 11-year cycle is weak or absent. Only two good examples of it were found in the 4,000 years. A cycle appeared at 12.5 years, a group at 13 and 14.5, some at 16 and 17, and strong cycles close to 20 years. This result is essentially repeated in the 736 years of Hudson River varves recently published by Dr. Chester A. Reeds, of New York.

In 1912 a large number of fragments of swamp cypress, *Taxodium distichum*, described to me as Pleistocene, were secured in the peat beds north of Dresden.

five-year cycle lasting for twenty years. If we pick out just that twenty years, harmonic analysis will show that cycle; if we try forty years, such analysis can only give the cycle at one half amplitude; if we have one hundred years of data the amplitude is only one fifth of the real value. One sees that this effect is exactly opposite to the effect on permanent astronomical cycles, which are strengthened by increasing length of data.

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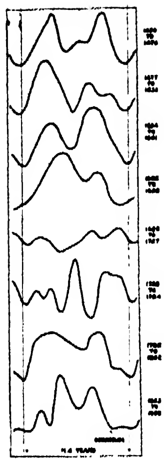


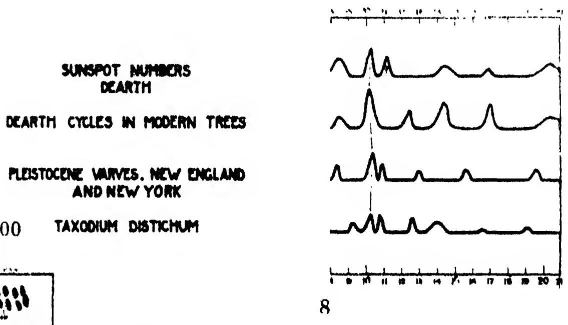


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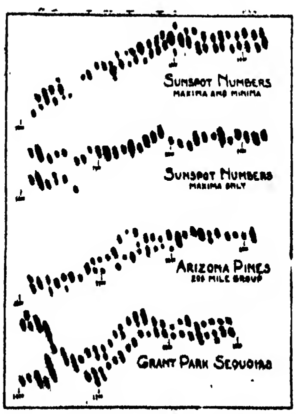


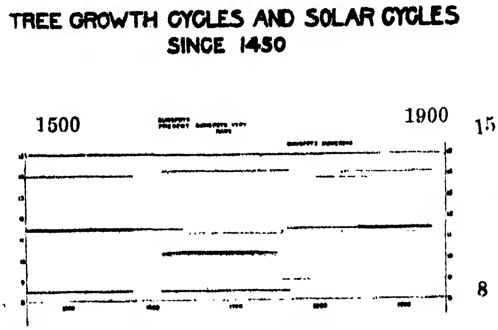


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PLATE 4: 12. HELLMANN CYCLE IN ARIZONA PINES AND ITS ABSENCE NEAR 1700 IN DEARTH OF SUNSPOTS; THESE CURVES WERE PUBLISHED IN SAME VOL. I, PG. 103; THE LAST THREE SHOW INTERFERENCE OF OTHER CYCLES. 13. "RESIDUAL PLOTS," CYCLOGRAM TYPE, SHOWING DEARTH CYCLES, 1650–1750, AT 8½, 10 AND 14 YEARS. 14. SAME PLOTTED IN TERMS OF CYCLE LENGTH AND TIME. 15. GEOLOGIC CYCLES COMPARED WITH SCHUSTER'S PERIODOGRAM OF THE SUNSPOT NUMBERS. 16. CYCLES IN ICE AGE MATERIAL COMPARED TO DEARTH CYCLES IN SUN AND TREES.

The total rings measured were 1,260 in number, distributed in four specimens giving long sequences of rings that appeared to be nearly free from errors. One five hundred year record gave a strong cycle at 10.9 years; another gave a good cycle at 10.0 years. Others were not particularly satisfactory, owing to the complacency of the growth. There are here some items of resemblance to the varve cycles just described (see Fig. 16, lowest curve).

In 1929 and 1930 collection was made of some 38 tertiary sequoias, silicified, from Specimen Ridge in the Yellowstone National Park, with results shown in the third curve of Fig. 15. These fossils were largely secured by Messrs. Mason and Reade as far as possible from one single horizon of petrified stumps. Probably many of them were living trees at the same time. Like the corresponding species to-day, the coast redwood, they are cross-dated with difficulty, for there are no distinctive drought rings to serve as guides, as in the giant sequoias and the pines of dryer regions. The counting therefore lacks the precision of cross-dated material, but yet is thought not likely to have errors that would change the results. So each tree record was counted carefully by Mr. H. F. Davis, over 11,000 rings measured, plotted and analyzed by him. This resulted in a surprising number of cycles between 11 and 12 years. I have personally repeated the analyses and have confirmed the frequency of the prominent Hellmann cycle at 11.2 to 11.8 and the usual cycles at 8½, 10, 14, 17 and 19. Some of the sequences gave groups of cycles so closely alike that it may be possible to cross-date by that means. That is a new problem to be tested later.

Several years ago the late Professor Udden, of the University of Texas, discovered lamination in anhydrite material forming a drill core brought up from some 1,500 feet in depth in Culberson County, Texas. He became satisfied of the annual character of the layers and by aid of a grant from the Carnegie Institution caused them to be measured. He thought there might be an error of the order of 2 per cent. in layers lost. The longest good sequence of layers studied has 1,443 years. The measures were turned over to Dr. E. L. Dodd for cycle analysis. He made a report showing the presence of cycles at 10, 11, 19 and 33 years. I was fortunate enough to secure a copy of this series of measures and have checked the analysis and confirm Dr. Dodd's results. I find cycles at 7 to 7.5 years, 8.8, a very prominent Hellmann cycle at 11.4, a group between 14 and 15 years, a faint one at 17.5 years and a little better one at 19 years. I found only a weak cycle at 10 years, as shown in Fig. 15, last curve.

These various analyses of modern and past climates when brought together show two chief results of interest to us. First, all these terrestrial cycles from modern trees and geological sources approximate in length the cycles in sunspot numbers (see Fig. 15, fourth curve), and second, they exhibit the two types of cycle complex or mixture already observed historically in the sun and trees, namely, the present common type, dominated by an 11.4 year cycle, and the dearth type, containing a 10-year cycle with about the same minor cycles in each group. The first of these types is shown in Fig. 15. This figure brings out the agreement found in modern trees, in buried trees, living perhaps 2,000 years ago, in Miocene sequoias from Yellowstone Park, in Udden's Permian anhydrite from Texas, with Schuster's periodogram of the sunspot numbers—an evident similarity outlining an immense interval of time.

But there is evidence that this cycle complex was not continuous from Permian times to the present, for the Pleistocene varves and logs of swamp cypress, *Taxodium distichum*, probably of the same age, give the dearth cycles of sun

and trees. Fig. 16 shows the cycles in sun and trees from 1600 to 1750, and below, the varve and cypress cycles. One notes that these Pleistocene cycles resemble the terrestrial and solar cycles near 1700 A. D., when there were many successive years without sunspots.

In this review of cycles in past climates it seems difficult to avoid the conclusion that these terrestrial cycles are connected with solar cycles. At the same time we get an idea of stability in the source of these cycles, even though the terrestrial results are sometimes complex.

### IV. Characteristics in Climatic Cycles

Attention should be called to the general resemblance between tree growth and solar cycles in their discontinuous or fragmentary character. When examined in cyclograms they look alike, save that the recent solar record is more apt to have only one cycle at a time. Before 1800, however, it had a mixture. The solar cycle is discontinuous, made up of substantial fragments. At the time of its discovery, somewhat less than one hundred years ago, it must have seemed very unstable, as a century of changes had just taken place: four cycles at about 9 years each, after 1750, then three cycles averaging 14 years, then one at 7, and then one or two at 11, but since that time it has been very constant at about 11.4 years.

Cycles in trees and climate seem apt to display similar changes, but they also display more cycles at one time, thus causing confusion. This may be persistence of cycles after the cause has changed, possibly a biological character. The cause may be persistence of cycles in the sun in some form less conspicuous than the usual smoothed annual sunspot numbers. Records in trees are very subject to a strong 2-year variation in which successive years tend to present opposite extremes. A similar character in weather has often been discussed, and similarity may be found to the cycle of 25 months quoted by Abbot in his solar radiation work. We must remember that cycles of two or three units are the most frequent to occur in accidental data. An approximate two-year cycle could be the cause of the great scattering of individual yearly values in rainfall and tree growth. In a large part of the analyses here quoted, the tree record has first been smoothed by a very simple formula $N = \frac{(n-1) + 2n + (n+1)}{4}$, which nearly eliminates the 2-year variation and gives an opportunity for longer cycles between 5 and 35 years to be observed.

Extensive testing work has been done to find if the long tree records can be distinguished from accidents and it is found that they can be so distinguished, if 150 or 200 years in length. The first criterion is the presence of a greater number of long cycles. This establishes a different type of periodogram from accidental sequences in which increasing prominence is given to the shorter cycles.

We find in terrestrial records certain long cycles that result from interference between short solar cycles already mentioned. In the solar records we have the Hellmann cycle and also a cycle at $8\frac{1}{2}$ years; the interference time between these two is 34 years, which gives us the Brückner cycle, frequently observed in tree growth. It is mentioned by Dr. Dodd as present in Udden's anhydrite measures from Texas. The interference between 14-year cycles and 11.4 is about 57 years. The Arizona trees show a strong cycle of this length between 1170 and 1500 A. D. The interference between the most common values of the 10 and 11-year cycles (about 10.3 and 11.4) is closely 100 years. This cycle was noted by Michelson in his analysis of the sunspot numbers. Many years ago it was found by the writer in Hunt-

ington's measures of the big sequoias as very prominent for nearly 2,000 years. Later it has been confirmed, but not specially studied, in accurately dated sequoia records. In the 1,200-year Arizona pine record a 100-year cycle is very prominent, indeed. All these scattering items sustain the idea of a relationship between the changes in the sun and the cycles in tree growth.

### V. Conclusion and Comment

The dating and measurement of the 250,000 annual rings of trees and the application to them of improved forms of cycle approach and an assured climatic interpretation of tree growth lead us to view climatic cycles as real cycles, distinguishable from accidents if shown in long sequences; appearing in a mixture of three or four cycles, long since found in sunspot records. The cycles seem to be discontinuous but occur in substantial fragments. Of these the most important is the Hellmann cycle, which in accordance with the evidence given above is considered to be a terrestrial reaction to forces operating in the body of the sun and caused through the agency of solar radiation.

In lack of a line of physical causation the relationship here stated is based on circumstantial evidence, but that evidence is very strong and a physical relationship through radiation is entirely reasonable. In fact, in these days it is not denied by any one that solar changes must effect terrestrial conditions; it is merely felt that such effects are too small to be found. The result of these tree ring investigations then shows that such effects are sometimes large enough to appear extensively in the growth of trees.

If climatic and tree growth cycles are discontinuous, can they be made of value in prediction? The answering thought is that long-range prediction, if possible, is far in the future. We must first know the actual climatic cycles as they are and then discover, also, the factors that bear upon their interruption. A considerable number of beginnings and endings seem to be associated with the centennial disturbance above referred to. In regard to shorter cycles a considerable number have been found to begin or end at sunspot minimum or maximum, with a probable preference for the minimum. Yet sometimes a short cycle passes through a minimum without change. Important information on this subject will be found in the immensely long records of the giant sequoias. The Hellmann cycle, and other cycles that seem to be associated with it, reappear at various times in the last 3,000 years. When these various recurrences are analyzed for a major cycle, some length of the order of 280 years has seemed to apply successfully. This particular study has received the name of "cycle succession."

It must be fully recognized that thus far we have dealt with very limited parts of the world. There are, for example, stores of information in our southern forests. We know practically nothing of the tree reaction in the southern hemisphere. Fine groups have been obtained from near the northern Arctic Circle, but not yet accurately studied. It is perfectly evident that the distribution about the earth of the effects of radiation from the sun must be very complex. Yet I can not agree with the meteorologists who consider that the complexity of this distribution accounts for all climatic changes. I think, on the contrary, it is a question of hard work to find regions in the world whose climatic changes can most easily be related to solar influence, and then persistent work is needed to understand the regions that are more complex. Perhaps some regions are too complex ever to give satisfactory solution, but as a better idea is developed of the nature of solar and terrestrial changes, we will be able to gather together data bearing upon world

changes. Probably it is another problem like that of distribution of tides.

Lastly, the next obvious step is to develop the biological reaction, the relation of ring width to environment and especially to climatic elements. It is true that there are some localities where a single element, like rainfall, dominates the growth, but even here other factors have influence and in most cases the interaction is very complex.

Upon the heels of this development we must have a mathematical technique specially adapted to the study of temporary and double-crested cycles; and finally an urgent need, and one difficult to satisfy, lies in the increased development of knowledge of the physics and mechanics of the solar atmosphere.

### Method of Reading Cyclograms

The method of reading cyclograms may be illustrated by an enlargement of Fig. 8 *g* and 8 *m*. Here, as in all cyclograms, each dot represents a full crest in the original curve whose analysis produced the diagram. The cyclograph, or analyzing instrument, is so constructed that, when set to analyze at a certain cycle length, the primary alignment of dots will be horizontal if the curve contains that cycle length (Fig. 8 *m*, A–A′). Simply for advantage to the eye, the primary row of dots is repeated two or more times in each pattern (Fig. 8 *m*, A–A′ and A–A′). Now if a faint row of dots (B–B′) appears between the main horizontal rows it means that two crests in the curve rather than one represent the particular period at which the analyzing was done. The entire series of diagrams in Fig. 8 was photographed with the cyclograph set at 11.4 years. Hence one may readily see not only that the 11.4-year cycle is present and dominant but also that in the majority of cases it possesses two crests which, by definition, represent the Hellmann cycle.

If the curve under analysis possesses a period different in length from the one at which the instrument was set, its presence will be revealed by an oblique or secondary alignment (Fig. 8 *m*, C–C′). The row of dots, D–D′, indicates the double-crested nature of the cycle represented by C–C′. In fact, the slant downward to the right in Figs. 8 *g* and 8 *m*, as well as in *h*, *i*, *j*, *k* and *l*, is caused by a double-crested 14-year cycle which, it is evident, exists both in the tree records and in the sunspot numbers.

# MARCO POLO AND SOME MODERN THINGS OLD IN THE ASIA OF HIS DAY

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

## THE MAN

MARCO POLO (1254–1325 or '26) was 15 years old when his father (Nicolo) and uncle (Maffeo Polo) returned to Venice in 1269 from their first visit to the East. When the brothers left Venice on their first trip is not known, but in 1260 they were in Constantinople on a trading venture and from there they traversed central Asia to the court of Kublai Kaan in Mongolia. On their second journey Marco Polo accompanied them. They left Venice in 1271 and after a journey across Asia of about three and a half years reached the court of the great emperor in 1275. Kublai received the elders very cordially and seems to have formed an especial liking for Marco, who was then about 21 years old. Marco was taken into the service of the Kaan and served in local administrative positions and was also sent on distant missions over almost the whole of Kublai's empire. He found that Kublai was interested not only in administrative matters but also in a wide knowledge of the peoples of his great empire, their lives as influenced by their environments, their industries and commerce, the natural history of their provinces, etc. These matters Marco seems to have noted either in writing (according to Ramusio) or in his memory, and the reports he made to Kublai had no small part in determining his high standing with the emperor. Indeed, in chapter xvi of the Prologue to Marco's book, Kublai is quoted as saying of the young Venetian, when he returned from a mission to Yun-nan, that "If this young man live, he will assuredly come to be a person of great worth and ability." Later, out of these notes and memories, was constructed one of the greatest travel books of the world.

The Polos remained in China so long that they doubtless feared that the great Kaan or his successor would never let them go. In 1292, Kublai desired to send the Lady Kokachin of his court as wife to his nephew Arghun, Khan of Persia, and when the long inland route seemed too hard for the tender 17-year-old maiden, and too filled with dangers, the envoys desired to return by sea. But these envoys were not sailors and the Polos were, so it seems that the Persians asked the Kaan to let the Venetians conduct them by water. This was strongly seconded by the Polos, who saw here an opportunity and means to return safely to Venice with their gathered wealth. At last Kublai consented reluctantly, but having done so he fitted the party out lavishly and dismissed the Polos with many royal gifts. And so early in 1292 they left the port of Zayton (Chinchew in Fokien) in 13 ships, with a suite of some 600 persons, not counting the sailors.

The voyage was ill-starred and long, but the Polos and the Lady Kokachin reached Hormuz on the Persian Gulf late in 1293, having lost two of the three envoys and most of their suite on the way. The lady, who parted from them with many tears, was sent to the Persian court and the Polos went to Tabriz and after a long stay there proceeded by way of Constantinople to Venice, which they reached in 1295 or 1296. They had been gone about 24 years [1271–1295 or

1295], 17 of which (1275–1292) had been spent at the court of the Great Kaan. The passage of these years had brought many changes in Venice and in our travelers. According to Ramusio they had difficulty in establishing their identities, but finally they succeeded, and with their wealth the Polos became substantial citizens of Venice.

Of the three, Marco became the most prominent. His accounts of the wonders seen, of the great wealth of Kublai and indeed of all Cathay, and his own display of wealth, led to his being dubbed Marco Milioni and Il Milioni—the millionaire or the man who speaks in millions. Indeed, the court in which he lived was called Corte del Milione, and his house and family the Ca' Milion.

As such a prosperous citizen of Venice, Marco Polo would probably have spent the remainder of his days, and his great book would probably have never been written but for a fortunate internecine war between the two republics, Venice and Genoa, each striving to control the trade of the eastern Mediterranean. This war went on with varying successes for both sides, till in 1298, the Genoese, having won a considerable victory, sent an armada against Venice itself. The Venetians hastily fitted out a fleet to join their forces already out at sea looking for the Genoese. One of these galleys was commanded by the distinguished traveler, Marco Polo.

The fleets met off the island of Curzola on the Dalmatian coast, and in the great battle the Venetians were overwhelmingly defeated. Marco's ship was captured and he was taken prisoner and carried to Genoa where he was thrown in prison. Here he met a fellow-prisoner, a man of considerable literary attainments, Rusticiano of Pisa, whose pen was destined to write Marco Polo's book and make history. Presumably Marco, to while away the weary hours, told Rusticiano of the wonders he had seen, and doubtless Rustician persuaded Il Milione to dictate the account of his travels. However, Marco apparently reinforced his memory during this long narration with his notes, since one chronicler avers that he was permitted to send a messenger to fetch them from his father in Venice. At any rate it is well established that Marco was imprisoned in September or October, 1298, was set free in July, 1299, and was probably back in Venice by October, 1299. But in that 10-month prison interval Rustician had written Messer Marco's story, fortunately for the whole world.

Marco's life, from the time of his return to Venice in 1299 till his death in 1324 or 1325, was that of a well-to-do citizen of his native city. His name is found in the records from time to time but without connotation of anything particularly remarkable or unusual. He was probably buried as he wished in the church of San Lorenzo, but no monument was erected, for to his contemporaries he was but a teller of wild tales which their minds could not take in as having a basis of truth. The church of San Lorenzo was rebuilt from its foundations in 1592 and all traces of the burial vault of our traveler are lost. Further, it may be remarked that no authentic portrait of Marco Polo is extant. Those sometimes seen are all products of the imagination, are efforts of the artists to reproduce the lineaments of the Traveler as each conceived them.

## THE BOOK

The man has been dead these 608 years, but his book survives and will so long as time endures. The preponderating evidence is that Rustician wrote the narrative of our medieval Herodotus in French, and very bad French at that. In any case the book had a certain popularity and was presently translated into other languages. Even to-day there are extant about 92 MSS—45 in Latin, 21 in Italian (various dialects), 18 in

French, 6 in German, 1 in Spanish and 1 in Irish—so far as they are known. There are many printed editions, beginning with the German version issued at Nuremberg in 1477. How many editions in all have been issued I can not say—88 had been listed in 1921. Probably this list is far short of the actual number.

Now it should be noted that from the first dawn to the recent past, no credence has been given Il Milione's book—it has by many been considered a parallel work to "The Thousand and One Nights." Further the story is told that, long after Marco's death, in the Venetian Masques there was generally a representative of Marco Milioni who told "big stories" to "tickle the ears of the groundlings." Indeed, one writer says "No faith was put in him because of the extravagant things that he recounted." Further, a contemporary chronicler is quoted that on his death-bed the Traveler was begged by his friends to retract his improbable stories. Indeed, when I was a boy I read Marco Polo, Baron Munchausen and "The Thousand and One Nights"—all on the same level of improbability. Further, in 1878, there was published at Milan "Giulio Verne. I Viaggi di Marco Polo," etc. So even at that late date, in his own country, our Traveler was without honor.

But time and the patient work of scholarly editors have brought the world to a better and truer estimate of the medieval Herodotus, and let it be said in their high praise that much and the best of this work has been done by Englishmen. However, the first edition to be listed is that of G. B. Ramusio in his "Navigationi e Viaggi" of 1559. Most of the alleged facts of Marco Polo's personal history are contained in the preface to the second volume of this Collection. In this preface dated 1553, Ramusio states that these facts came to him from a senator of Venice (Gasparo Malpiero) who in turn had them from his father and grandfather—the latter of whom was of a generation immediately after Marco's and who had lived in a house on the Corte del Milioni. In the same preface Ramusio states, "I have deemed it reasonable to publish his book with the aid of several copies written (as I judge) more than 200 years ago, in a perfectly accurate form, and one vastly more faithful than that in which it has been heretofore read." This version, with its personal details, has been deemed of such value by Yale and Cordier that many parts of it have been set in square brackets in their translation. Some of these will be quoted later. Furthermore, Baldelli-Boni in 1827 republished the Rasmusian version with numerous notes, and Bürck's German edition of 1855 is mainly a translation of Ramusio with notes from Marsden.

In 1818 William Marsden published in London the first great English edition with a valuable introduction and notes. In 1824, the Société de Géographie of Paris published the most valuable manuscript (the one nearest to Rustician's original). This was followed in 1865 by G. Pauthier's learned version, based on the collection of three unpublished manuscripts in the great library of Paris. Then followed in rapid succession in 1871 and 1875 Colonel Henry Yule's first and second editions, in which that learned geographer firmly established Marco Polo's travels to, in and from Cathay as the most extensive and exact of those of any of the medieval travelers. And last of all is the Yule-Cordier edition in two great volumes, containing Yule's notes for a third edition which he did not live to bring out. These were turned over by Yule's daughter to her father's friend, the great Sinologist, Henri Cordier of Paris, who brought out the third edition in 1903. This has been twice reprinted

—the second time in 1921. Those who seek to estimate the character of the man and his book are referred to this great work and particularly to Yule's words on pages 104–116 of the illuminating Introduction. Perhaps it will be well to quote the opening paragraph.

> That Marco Polo has been so universally recognized as the King of Mediaeval Travellers is due rather to the width of his experience, the vast compass of his journeys, and the romantic nature of his personal history, than to transcendent superiority of character and capacity.

Then let the reader peruse on pages 106 and 107 an eloquent summary of what this great traveler *saw* and *did*, and then he will be ready to agree that he *was* the medieval Herodotus, the greatest traveler of the Middle Ages and one of the greatest of all time.

From this great edition, one of the most scholarly works it has ever been my privilege to read and reread, the facts above have been collected and the words of Marco Polo, now to be set out, have been gleaned. But for this work, as fully a marvel of scholarly erudition as Marco's chapters are full of the marvels of the East, these notes of mine would never have been compiled. I envy the man who reads this great work for the first time.

## SOME PRESENT-DAY NEW THINGS OLD IN THE ASIA OF MARCO POLO'S DAY

From the great wealth of material in Marco's text and in the wonderfully illuminating notes of Yule and Cordier, it is not easy to choose when one would like to quote so much. As a naturalist, I am of course greatly interested in the multitude of natural history notes—and some one ought some day to collect and publish such notes pertaining to animals —Polo's sheep, *Ovis poli,* for instance. However, I shall herein confine myself to certain practises and discoveries of the people of Polo's day which we moderns have lately rediscovered.

### Naval Construction

Tremendous advances have been made in the construction of vessels in the very recent past, but some of these will now be shown to be old in Marco Polo's day.

*Multi-masted Vessels:* For perhaps hundreds of years the three-masted sailing vessel was considered the *ultima thule* of naval construction. I can remember when four-masted schooners were new and so extraordinary that people went miles to see them. Then came the five-, the six- and last the seven-masted schooner, and the world is now sure that the forest of masts on a vessel's deck will never have an addition.

But Marco Polo in his Prologue or Introduction to his Travels, speaking of the preparations made for the return of Arghun's envoys with the Lady Kokachin, in the charge of the Polos, says in Chapter xvii (Vol. i, p. 34)[1] that: Kublai "then caused thirteen ships to be equipt, each of which had [one deck and] four masts and often spread twelve sails." Again, in Book iii, Chapter i (Vol. ii, p. 249), Marco says, "The ship [in which merchants go to and fro amongst the Isles of India] hath but one rudder,[2] and sometimes they have two additional masts which they ship and unship at pleasure." Yule suggests that one of these was probably a bowsprit, which the Chinese occasionally use.

To work one of these great ships Polo states that 200 men were required—250–260 in the Ramusian version. Further,

[1] This quotation and the others to follow are taken from "The Book of Ser Marco Polo, the Venetian, Concerning the Kingdoms and Marvels of the East." Translated and Edited with Notes by Colonel Sir Henry Yule. . . . Third Edition Revised Throughout in the Light of Recent Discoveries by Henry Cordier (of Paris). London, John Murray, 2 vols. 1921 (third printing). The references are to book and chapter of Marco Polo's own work. For the convenience of the reader the volume and page references to Yule-Cordier are added in parentheses.

[2] Many European vessels of Marco's day had two rudders.

Ramusio states that formerly they used even larger ships than these. When the wind failed, these mariners got out sweeps, four men to a sweep. Again they had sailing tenders, which, with sails or sweeps, towed these great junks out of danger or into port.

*Water-tight Compartments:* These are supposed to be ultra-modern devices, the last word in modern shipbuilding practise to make sure the safety of our ships. But here is what Cordier interpolates from Ramusio's version, previously referred to. Marco, in Book iii, Chapter i (Vol. ii, pp. 249–250) states that in China:

> Moreover the larger of their vessels have some thirteen compartments or severances in the interior, made with planking strongly framed, in case mayhap the ship should spring a leak, either by running on a rock or by the blow of a hungry whale (as shall betide oft-times, for when the ship in her course by night sends a ripple back alongside the whale, the creature seeing the foam fancies there is something to eat afloat, and makes a rush forward, whereby it often shall stave in some part of the ship).[3] In such case the water that enters the leak flows to the bilge, which is always kept clear; and the mariners having ascertained where the damage is, empty the cargo from that compartment into those adjoining, for the planking is so well fitted that the water cannot pass from one compartment to the other. They then stop the leak and replace the lading.

*Planking and Caulking:* In these matters, the Chinese of our Traveler's day had anticipated the best modern practise in wooden vessels. Here is what he has to say about it in Book iii, Chapter i (Vol. ii, p. 250):

> The fastenings are all of good iron nails and the sides are double, one plank laid over the other, and caulked outside and in. The planks are not pitched, for these people do not have any pitch, but they daub the sides[4] with another matter, deemed by them far better than pitch; it is this. You see they take some lime and some chopped hemp, and these they knead together with a certain wood-oil; and when the three are thoroughly amalgamated, they hold like any glue. And with this mixture they do paint their ships.

Another practise recalls the extra-planking or sheathing applied to the bows of our tugs in northern harbors where ice abounds in the winter; and applied to the whole hull of a wooden whaling or exploring vessel setting out for the Arctic. Here follow Polo's own words in the book and chapter cited above (Vol. ii, p. 251):

> When the ship has been a year at work and they wish to repair her, they nail on a third plank over the first two, and caulk and pay it well; and when another repair is wanted they nail on yet another plank, and so on year by year as is required. Howbeit, they do this only for a certain number of years, and until there are six thicknesses of planking. When a ship has come to have six planks on her sides, one over the other they take her no more on the high seas, but make use of her for coasting as long as she will last, and then they break her up.

This multiple-planking was necessary after one year's work, because these vessels were made not of solid oak as are ours but of soft fir. It is then conceivable that at the end of a season's use the hull would be pretty well strained and open, and that the easiest method of repair is that indicated. The use of old hulks as coasting barges is strictly parallel with our modern practise.

*Sewed Planking:* Vessels with sewed or stitched planks are in use if not today then very recently on the Malabar and Coromandel Coasts of India, and I believe also in other parts of the world. Their pliancy makes them of great value as surf boats. But Messer Marco found them in use in his days and he so makes record in Book i, Chapter xix (Vol. i, p. 108), of their use at Hormuz on the Persian Gulf, in these words:

> Their ships are wretched affairs, . . . for they have no iron fastenings, and are only stitched together with twine made from the husk of the Indian nut. They beat this husk until it becomes like horsehair, and from that they spin twine, and with this stitch the planks of the ships together. It keeps well, and is not

[3] This anticipates "Moby Dick."

[4] Between the planks?

corroded by the sea-water, but it will not stand well in a storm.

The Indian nut is evidently the cocoanut, as is further made clear from its size (of a man's head) and the description of the white meat and the clear fluid. Incidentally this is the first reference to it known to me in the writings of a European. The beaten husk which becomes like horsehair is evidently the material known to-day as coir.

### Rapid Transit

When man progressed beyond the stage of foot travel, it was because he had tamed and made a servant of the horse and its allies. The journey of the Polos across central Asia to the court of Kublai Kaan was done either on horses or on camels. The far-flung conquests of Chinghis and Kublai were brought about by their well-organized armies of horsemen. But even here speed was limited.

*Horse-Post Express:* In the sixties of the last century, when the Central and Union Pacific Railways were being built across the high mountains and great plains of the United States, the mails were carried from rail-head to rail-head by the famous Pony Express. This rapid transit was effected by having relay and remount stations from 10 to 25 miles apart. Read Mark Twain's "Roughing It" and learn how a light spare rider raced at full tilt into a station and threw himself and the mail bag into the saddle of a fresh mount and was away at a gallop before the saddle was off his old horse. Thus the Pony Express carried the mails from Saint Joseph, Missouri, to Sacramento, a distance of 2,000 miles, in 8 days at a speed of 10 miles per hour and was the marvel of the time.

But the great Kaan had *his* Pony Express 500 years earlier. Thus Marco wrote in Book ii, Chapter xxvi (Vol. i, pp. 433–437) how from the royal city of Cambaluc (Pekin or Peiping) the Kaan had paved highways running to the various provinces. At every 25 miles on these royal roads was a *Yamb*, a "Horse-Post-House" or station, for the care and forwarding of travelers, but especially to expedite the movements of the emperor's messengers. Marco states that there were in the empire more than 10,000 stations and that more than 300,000 horses were kept for the use of these messengers.

To save horse-flesh, foot-runners were generally used. As in India in the recent past if not in the very present, each man was equipped with a belt set with bells to give notice of his coming. Between these post-houses, smaller stations were built every three miles and the runner carried the despatches only that distance and turned them over to the next man. However, in case the despatches called for greater haste and speed, then horses were used. The riders were equipped with bells, as were the foot-runners, and the chronicler thus writes of them (p. 436):

> They take a horse from those at the station which are standing ready saddled, all fresh and in wind, and mount and go at full speed, as hard as they can ride in fact. And when those at the next post hear the bells they get ready another horse and a man equipt in the same way, and he takes over the letter or whatever it be, and is off full-speed to the third station, where again a fresh horse is found all ready, and so the despatch speeds along from post to post, always at full gallop, with regular change of horses. And the speed at which they go is marvellous.

Marco's specific statements as to the speed of these couriers are exaggerated and contradictory. In this chapter he says that the runner will carry despatches from places 10 days off in a day and night and from 100 days distant in 10 days and nights. The horsemen on the other hand will do 200 or 250 miles in a day and as much in a night. Yet he notes that at night they have to go slower because they are accompanied by footmen with torches, and

the rider must accommodate his speed to that of the runner.

Then Marco adds a detail about the dress of the riders, which I think (but am not sure about) was also true of our Pony Riders. Here are his own words: "Those men [riders] are highly prized; and they could never do it, did they not bind hard the stomach, chest and head with strong bands." Had they not done so they would have literally been shaken to pieces. As an indication of how accurate Marco generally was in his observations, in speaking of the paved roads of Manzi as recorded by Ramusio, he meets a query in the reader's mind in the following statement (Book ii, Chapter lxxvii—Vol. ii, p. 189): "But as the Great Kaan's couriers could not gallop their horses over the pavement, the side of the road is left unpaved for their convenience." This, furthermore, is just what is found in the clay "shoulders" alongside our concrete roads in the United States to-day, and these soft shoulders are to-day utilized by horsemen in just the same way in order to save the horses' feet.

*Dog Sledges:* We have all known for a long time that in the Arctic—in Siberia, Alaska, around Hudson Bay and in Greenland—travel in the winter especially is by dog sledge. A few years ago we were all thrilled over the wonderful dash against time of Balto and his companions to carry diphtheria antitoxin to a stricken town in Alaska. Those of us who live in New York have seen the statue to this great-hearted dog in our Central Park near the old arsenal.

But our old Traveler writes of post dogs in Siberia in his Book iv, Chapter xx (Vol. ii, pp. 479–481). Whether he went there on a mission for the Great Kaan, or whether he got his information from others, can not be said, but his account reads like that of an eye-witness. He speaks of a king in the far north, Conchi by name, a kinsman of Kublai's, whose country was 13 days in extent and quite impossible for horses. Here post-houses were established a day's journey apart with 40 great dogs to draw the couriers from station to station. These worked thus:

> On a sledge they lay a bear-skin on which the courier sits, and the sledge is drawn by six of those big dogs that I spoke of. The dogs have no driver, but go straight for the next post-house, drawing the sledge famously over ice and mire. The keeper of the post-house however also gets on a sledge drawn by dogs, and guides the party by the best and shortest way. And when they arrive at the next station, they find a new relay of dogs and sledges ready to take them on, whilst the old relay turns back; and thus they accomplish the whole journey across that region, always drawn by dogs.

*Public Carriages:* One of the great conveniences of modern city life is cab service, and, in the present day of motor-cars, especially the taxicab. There is no need to argue this matter, but it may strike the reader as a bit unusual to learn that in the China of Marco Polo's day there were public carriages for hire in many of the great cities. Here is what Messer Marco says in Book ii, Chapter lxxvii (Vol. ii, p. 206) on this subject:

> In the main street of the city of Kinsay (Hangchau) you meet an infinite succession of these [public] carriages passing to and fro. They are long covered vehicles, fitted with curtains and cushions, and affording room for six persons; and they are in constant request for ladies and gentlemen going on parties of pleasure.

Yule remarks in a note that at one time such carriages were much more common in the great cities of the north of China than they are now. They were abandoned in China about the time that they were introduced in the cities of Europe. This disuse may have been either the effect or the cause of the neglect of the roads on which Marco has been quoted. There is no definite statement as to the motive power, but this is implied when he writes that the people are fond of "driving about the city in

carriages." Probably these were something like palanquins.

### Sanitary and Hygienic Matters

We of the present day think that we have carried sanitation to such a point of excellence that nothing in the past can measure up to our standards. It will then be of interest to quote Marco Polo on certain precautions which he found in vogue in China.

*Mouth and Nose Muffled:* In times of influenza epidemics and even when only possessed of a common cold, we are wont to keep mouth and nose covered when coughing and sneezing to prevent transmission of germs. In case of a surgical operation, the precautions taken seem almost exaggerated. The other day I saw a picture of an operating room, with the surgeon in the foreground having his whole face below his eyes covered with a mask. But according to the Preacher in Ecclesiastes "there is nothing new under the sun" as the following quotation from Book ii, Chapter xiii (Vol. i, p. 383) will show:

And you must know that those who wait upon the Great Kaan with his dishes and drink . . . have the mouth and nose muffled with fine napkins of silk and gold, so that no breath nor odour from their persons should taint the dish or the goblet presented to the Lord.

*Sputum Cups:* Modern medical and sanitary science has brought us the sputum cup or receptacle for use by those suffering from respiratory diseases, and at sanitariums for tubercular patients its use is *de rigeur*. As to its use in China in the thirteenth century let us hear our old Traveler. He writes in Book ii, Chapter xxxiv (Vol. i, p. 458) thus of the matter of Kublai's court:

And every one of the chiefs and nobles carries always with him a handsome little vessel to spit in whilst he remain in the Hall of Audience —for no one dares spit on the floor of the hall —and when he hath spitten [in the vessel] he covers it up and puts it aside.

*Drinking Cups:* Another widely used modern device to prevent the spread of communicable diseases is the individual drinking cup, which is generally thrown away after use. Marco Polo, on his voyage around India with the escort of the Lady Kokachin, found individual drinking cups in use in the province of Maabar (*i.e.,* the Coromandel Coast). Here is his statement (which the editors find in the Ramusian version only) taken from Book iii, Chapter xvii (Vol. ii, p. 342):

So also they drink only from drinking vessels, and every man hath his own; nor will anyone drink from another's vessel. And when they drink they do not put the vessel to the lips, but hold it aloft and let the drink spout into the mouth. No one would on any account touch the vessel with his mouth, nor give a stranger drink with it. But if the stranger have no vessel of his own they will pour the drink into his hands and he may thus drink from his hands as from a cup.

*Suspended Beds:* At the Marine Biological Laboratory of the Carnegie Institution of Washington at Tortugas, Florida, to prevent the inroads of omnipresent ants, we slept on cots suspended by iron rods passing through tin cups filled with kerosene oil. This is a common present-day practise in tropical countries to prevent attacks by various insect enemies and to secure better ventilation. A like device was found in use in Maabar by Marco Polo. In his Book iii, Chapter xvii (Vol. ii, p. 346), interpolated by Cordier from Ramusio's version, is the following account:

The men of this country have their beds made of very light canework, so arranged that, when they have got in and are going to sleep, they are drawn up by cords nearly to the ceiling and fixed there for the night. This is done to get out of the way of tarantulas which give terrible bites as well as of fleas and such vermin, and at the same time to get as much air as possible in the great heat which prevails in that region. Not that everybody does this, but only the nobles and great folks, for the others sleep in the streets.

*Ventilators:* Ventilation in hot countries, especially at night to help induce

sleep, is a matter of prime importance. Among the devices invented to meet this need is the coolie-operated punkah of India and our own efficient electrically driven fans. At Hormos on the Arabian Sea our medieval Herodotus writes in Book iii, Chapter xl (Vol. ii, p. 452) that:

The heat is tremendous, and on that account their houses are built with ventilators to catch the wind. These ventilators are placed on the side from which the wind comes, and they bring the wind down into the house to cool it. But for this the heat would be utterly unbearable.

Yule has an interesting note on these ventilators, which he calls "a kind of masonry windsail." He notes that such are common to-day throughout parts of Egypt, Mesopotamia, Persia and northern India, and he figures such a device from Persia. The reader who is sufficiently interested will find Yule's discussion in Vol. ii, pp. 452–453.

There is a present-day form of condenser for compound condensing steam engines called a cooling tower which works on this same principle. A tower open at top and bottom contains a multitude of pipes filled with steam from the low pressure cylinder. Over these pipes cool water trickles, is evaporated by the heat, and the vapor rises and passes out at the top, creating a current. Again, as in ice factories, the steam pipes with trickling water are simply placed on the roof for the wind to play over them.

*Gold Teeth:* The matter now to be considered is only remotely connected with the general heading above, but it does have some connection and it is so unusual and so interesting that it will be set forth last of all for this section.

One of the notable discoveries of modern prosthetic dentistry is the gold crown (and the bridge also) and its use to preserve badly decayed teeth, which left uncovered would not hold their fillings, and very soft teeth which would break down without such reinforcement. But our Venetian tells us in Book ii, Chapter i (Vol. ii, p. 84) that in the province called Zardandan:

The people of this country have all their teeth gilt; or rather every man covers his teeth with a sort of golden case made to fit them, both the upper teeth and the under.

Zardandan is a Persian word meaning "gold-teeth." The province is near the head-waters of the Mekong river. Whether the gold-teeth of these people were single crowns or a collective covered-bridge-like structure can not be said. The latter is probable. A later describer of these people says that they take the gold case off when they eat. However, in 1800, Marsden and also Raffles found the people of Sumatra using this casing, "sometimes indented to the shape of the teeth," and not removing it when eating or sleeping. Whatever interpretation we put on this device, it is certainly an approach to the present-day crown, the modern "gold-tooth."

### Building, Clothing, etc.

Marco Polo notes many things of interest under these heads, but it is difficult to segregate those which are old and yet new. However, some remarks of his about the uses of the bamboo, which he calls the "cane," may be of interest. This plant is of universal distribution throughout the East, and Marco notes three uses in his book.

*Bamboo Buildings and Roofs:* Throughout the Indian Archipelago to-day, houses are made of split bamboo and are roofed with bamboo tiles. Ser Marco tells us in his Book i, Chapter lxi (Vol. i, p. 299) that Kublai built in his pleasure park at Chandu (Kaipingfu) a summer palace of "cane." The roof is of especial interest and is thus described—the part in square brackets being taken from Ramusio:

The roof, like the rest, is formed of canes, covered with a varnish so strong and excellent that no amount of rain will rot them. These canes are a good 3 palms in girth and from 10

to 15 paces in length. [They are cut across at each knob, and the pieces are split so as to form from each two hollow tiles, and with these the house is roofed; only every such tile of cane has to be nailed down to prevent the wind from lifting it.]

It is notable that the describer does not say how the "joints" are "broken" by a third tile. Two tiles are laid side by side, concave surfaces up, and their two adjacent edges are covered by the third laid with the convex surface up. This is just the arrangement which one sees in all pictures of Chinese roofs to-day.

*Bamboo Ropes:* In China to-day, cables and tow-lines used by river-boats and "tracking" lines on the Yangtse are made of bamboo. Presumably the first mention of them is that in Messer Marco's Book ii, Chapter lxxi (Vol. ii, p. 171). Speaking of travel on the river Kian (Yang-tse-Kiang), he states that:

You must know that the vessels on this river in going up-stream have to be tracked, for the current is so strong that they could not make head in any other manner. Now the tow-line, which is some 300 paces in length, is made of nothing but cane. 'Tis this way: they have those great canes of which I told you before that they are some fifteen paces in length; these they take and split from end to end [into many slender strips], and then they twist these strips together so as to make a rope of any length they please. And the ropes so made are stronger than if they were made of hemp.

*Exploding Bamboos:* The matter now to be considered concerns a use of the bamboo which is apparently the first on record. One can hardly read a book of travel and exploration in the East in which it is not recorded that the travelers put green joints of the bamboo on their fires in order that the explosions may drive away wild beasts. Here is what our Traveler says on the subject in writing of the province of Tebet in his Book ii, Chap. xlv (Vol. ii, p. 43). It should be noted first that Mangu Khan, Kublai's elder brother, had literally laid waste this province, with the result that bamboos had grown up everywhere, and ravenous wild beasts had so enormously multiplied as to make it very dangerous to traverse the country. Marco has this to say about this use of bamboos in this region:

And let me tell you that merchants and other travellers through that country are wont at nightfall to gather these canes and make fires of them; for as they burn they make such loud reports that the lions [*i.e. tigers*] and bears are frightened, and make off as fast as possible; in fact nothing will induce them to come nigh a fire of the sort. . . . I will tell you how it is that the canes make such a noise. The people cut green canes, of which there are vast numbers, and set fire to a heap at once. After they have been burning awhile they burst asunder, and this makes such a loud report that you might hear it ten miles off.

*Bark Cloth:* When the first voyagers traversed the South Seas, they found the natives making cloth of the bark of a tree and using it for clothing. Nor has this custom entirely died out yet. Further we read that during the Great War the Germans made and wore paper clothes. This is essentially the same thing. But Marco Polo found bark cloth used in the China of the late 1200s. His account unfortunately is very brief and entirely devoid of details. He says in Book ii, Chapter lix (Vol. ii, p. 124) in speaking of the people of Cuiju (Kwei-chau) that: "You must know they manufacture stuffs of the inner bark of certain trees which form very fine summer clothing."

### Agriculture, Stock-Raising and Food Production

Marco Polo mentions four such matters, which, in addition to being probably first records, are of sufficient interest to be noted.

*Huskless Barley:* Barley is a cereal which seems to have originated in western Asia where it has been cultivated from the earliest times. It is the hardiest of the grains and has the highest range both in altitude and latitude.

Among the desiderata of plant breeders to-day are grains devoid of "beards" or pointed husks. Such get into the clothes of the laborers in grain fields, and when eaten by farm animals may cause considerable trouble. The Encyclopedia Britannica records the fact that there are two huskless species but without definitely assigning a habitat. They seem to be Asiatic in origin and possibly Himalayan. But our old Traveler states that in his day there was found a huskless form in the province of Badashan, north of Afghanistan (Book i, Chapter xxix; Vol. i, p. 158).

*Hybrids of Yak and Cow:* The yak, both wild and domesticated, is found in Central Asia. The wild forms are much larger and stronger than the tame ones. I do not know if any modern attempts have been made to cross them with cattle, but Ramusio makes Marco say in Book i, Chapter lvii (Vol. i, p. 274) that in the kingdom of Erguiul (not identified): "They cross these [yaks] with the common cow, and the cattle from this cross are wonderful beasts, and better for work than other animals." I do not know, but I suspect that this is the first record of a man-made hybrid between mammals. A recent man-made mammal hybrid is the cattalo—a cross between the domestic cow and the buffalo. It has the hardihood of the buffalo and the good beef-producing qualities of domesticated cattle.

*Milk and Its Products:* The sanitary production and handling of milk and its products are among the triumphs of modern hygiene. In my morning paper I to-day read an advertisement of milk cultured with *Bacillus acidophilus.* To-day we have various kinds of milk and a great variety of cheeses first sterilized and then cultured with particular kinds of bacteria and molds (in the cheeses only) in order to produce distinctive products with particular flavors.

Now *Kumiz,* or as he wrote it *Kemiz,* had been known long before Marco Polo's day—its first mention seems to be found in Herodotus (Book iv, Chapter ii, of Rawlinson's translation)—but Marco's narrative brought it to the attention of western Europe. He writes in his Book i, Chapter liii (Vol. i, p. 259) of the Tartars that "Their drink is mare's milk, prepared in such a way that you would take it for white wine; and a right good drink it is, called by them Kemiz."

For full details about the preparation and use of *Kumiz* see Yule's interesting notes in Book i, pp. 259–260. Of especial interest just here is the following quotation from the opening paragraph of his notes:

> Fresh mare's milk is put in a well-seasoned bottle-necked vessel of horse-skin [Yule gives a figure of this]; a little *Kurut* [sour butter-milk left after churning] or some sour cow's milk is added; and when acetous fermentation is commencing it is violently churned with a peculiar staff which constantly stands in the vessel. This interrupts fermentation and introduces a quantity of air into the liquid. . . . After three or four days the drink is ready.

*Kurut,* another milk product, was as staple a food among the Tartars as *Kumiz* was a drink. On this point, in his next chapter, our medieval Herodotus tells how the Tartars in their warfare make long forced marches carrying a minimum of supplies. The chief of these is a "dried milk," or *Kurut,* as it was called, in the preparation and use of which the Tartars seem to have long anticipated our modern evaporated milk. Messer Marco describes both preparation and use in his Book i, Chapter liv (Vol. i, p. 262) in the following phraseology:

> They also have milk dried into a kind of paste to carry with them; and when they need food they put this in water, and beat it up till it dissolves, and then drink it. [It is prepared in this way; they boil the milk, and when the rich part floats on the top they skim it into another vessel, and of that they make butter; for the milk will not become solid till this is removed. Then they put the milk in the sun to dry. And when they go on an expedition, every man takes some ten pounds of this dried

milk with him. And of a morning he will take a half pound of it and put it in his leather bottle, with as much water as he pleases. So, as he rides along, the milk-paste and the water in the bottle get well churned together into a kind of pap, and that makes his dinner].

*Sago Flour:* How early sago flour was made in the east and when its use came to the knowledge of Europeans can not be said. But Ser Marco, on his voyage around Sumatra, found it being made and used in the Kingdom of Lambri. Here read his words from Book iii, Chapter xi (Vol. ii, p. 300):

They have a kind of trees that produce flour, and excellent flour it is for food. These trees are very tall and thick, but have a very thin bark, and inside the bark they are crammed with flour.

Notable is the bare statement utterly devoid of details. However, Messer Marco certainly saw the sago flour being made, for in Ramusio's version the details of its manufacturing are given and it is stated that Polo brought some of the bread home with him to Venice. This Ramusian account Yule gives in full (Vol. ii, p. 305) and below it Cordier (in the third edition) has quoted A. R. Wallace's almost parallel account from his "Malay Archipelago." It is plain that each account is that of an eye-witness.

## Governmental Affairs

The empire of Chingis Kaan and of his successors (his sons and grandsons) covered practically the whole of Asia and even included southeastern Europe. His aim seems to have been to subjugate the whole world, and before his death, its extent did include half the human race. Of this great realm, of which, in the day of the Polos, Kublai was at least the nominal head, Yule writes thus: "In Asia and Eastern Europe scarcely a dog might bark without Mongol leave, from the borders of Poland and the Gulf of Scanderoon to the Amur and the Yellow Sea."

It would be interesting to dig out of our old Traveler's book a great variety of notes on the way in which this great empire was administered, but space will only permit reference to two matters in which our practises of the present day were anticipated.

*Paper Money:* One of the prime necessities in this great empire was a universal currency and one of which large amounts could be easily transported. This Kublai met by manufacturing and issuing paper money "so light that ten bezants' worth does not weigh one gold bezant." In his Book ii, Chapter xxiv (Vol. i, pp. 423–426) Ser Marco writes most interestingly of Kublai's "Mint, . . . in the which he hath his money coined and struck." This seems such an improbable matter that he adds . . . "tell it how I might, you would never be satisfied that I was keeping in truth and reason." His speaking of the millions of money issued from the "Mint" of Kublai is probably one of the things that led to Marco Polo's being called "Il Milione" in Venice years later.

This paper money was made of the bark of the "Mulberry Tree." Its production is thus described by the Chronicler:

What they take is a certain fine white bast or skin which lies between the wood of the tree and the thick outer bark, and this they make into something resembling sheets of paper, but black. When these sheets have been prepared they are cut up into pieces of different sizes. The smallest of these sizes is worth a half tornesel; the next, a little larger, one tornesel; one, a little larger still, is worth half a silver groat of Venice; another a whole groat; others yet two groats, and ten groats. There is also a kind worth one Bezant of gold, and others of three Bezants, and so up to ten. All these pieces of paper are [issued] with as much solemnity and authority as if they were of pure gold or silver; and on every piece a variety of officials, whose duty it is, have to write their names, and to put their seals. And when all is prepared duly, the chief officer deputed by the Kaan smears the Seal entrusted to him with vermilion, and impresses it on the paper, so that the form of the Seal remains printed upon it in red; the Money is then authentic. Any

one forging it would be punished with death.] And the Kaan causes every year to be made such a vast quantity of this money, which costs him nothing, that it must equal in amount all the treasure in the world.

This Mongol paper currency had no metallic basis and of course underwent great fluctuations. Furthermore, it was not the first issue in China. Yule states that the use of paper money there goes back to the sixth century, that the first Mongol issues were in 1236, while Kublai's extended from 1260 till his death (1294). For a discussion of these issues and their fluctuations in value, see Yule's and Cordier's erudite notes (vol. i, pp. 426–430). These issues of paper currency without any metallic basis have a parallel in many propositions of to-day (1933) to inflate the currency of the United States by the simple expedient of using a printing press.

*Fire Alarms:* One of the functions of local government is the detection and extinguishing of fires. The traveler through New England, New York, New Jersey and Pennsylvania will frequently see in the villages a primitive, inexpensive and efficient fire alarm apparatus. This consists simply of a heavy wagon tire, or better still a locomotive tire, sawn in two at one place and the ends at the cut sprung apart for better resonance. Hanging by a chain is a hammer. The deep booming sounds from the struck tire summon the villagers to help put out the fire.

It is interesting to find that the Chinese had devised and were using essentially the same apparatus in Marco Polo's day. In his Book ii, Chapter lxvi (Vol. ii, p. 189) in speaking of the governing of the city of Kinsay (Hangchau) Marco states that:

Within the city there is an eminence on which stands a Tower, and at the top of the tower is hung a slab of wood. Whenever fire or any other alarm breaks out in the city a man who stands there with a mallet in his hand beats upon the slab, making a noise that is heard to a great distance. So when the blows upon this slab are heard, everybody is aware that fire has broken out, or that there is some other cause for alarm.

In Cambaluc (Pekin) Kublai had a high tower with a bell in it to give alarm when struck. However, this was used primarily to strike the hours and for a curfew signal. This curfew matter was, moreover, not new to the Polos, since their Venice and all other European cities had had such a law for a long time. William the Conqueror brought the curfew law to England.

## Miscellaneous Matters

There are a few other matters described by Marco which do not fit in any of the sections above, but which are of sufficient interest to merit brief mention.

*Block-Printing:* The question whether or not Marco Polo had anything to do with the introduction of block-printing into Europe is one that has been much debated. Yule has shown the inaccuracy of these contentions (Introduction, Vol. i, pp. 138–141). In short, there is no evidence that our Traveler did anything of the kind. However, he certainly brought back the information that block-printing was known in his time in China, for the paper money described above was certainly printed from blocks and then the seal was applied by means of another block. This conclusion I draw from Yule's reproduction (to face p. 426, Vol. ii) in two colors of a banknote of the Ming Dynasty. None of Kublai's currency seems to have survived, but as indicated some has been preserved from the Ming which followed immediately (1368) after the Mongol rule.

*Docking Horses' Tails:* In my boyhood in the mountains of West North Carolina, in winter and with bottomless roads, travel was almost wholly on horseback. On such roads a horse's tail would soon become loaded with mud and in cold weather this would soon freeze.

Hence it was the custom to tie or knot the tail high up. Later came the practise of bobbing the tails of horses, partly for the reason given but largely to give the horses a smart appearance. This was all right in winter, but was a great deprivation to the animal in fly-time. However, it did save the rider a great deal of annoyance, as I can testify.

Probably this is an old and widespread practise, and doubtless well known to those who study the evolutions of customs and habits of mankind, since similar needs lead to the development of similar processes and practises among people widely separated. At any rate it was a familiar thing in the China of Messer Marco's day, as we may read in his Book ii, Chapter xlix (Vol. ii, p. 78). In speaking of the people of the Province of Carajan (in Yun-nan in the upper Irrawadi valley), he says, "And you must know that the people dock two or three joints of the tail from their horses, to prevent them from flipping the riders, a thing which they consider unseemly."

*Cooking at High Altitudes:* It is of course widely known nowadays that at great altitudes it is difficult to cook foods by boiling, since water under diminished pressure boils at too low a temperature. While crossing the Pamir, the "Roof of the World," Ser Marco found (Book i, Chapter xxxii, Vol. i, p. 171) that the region was very lofty and cold and adds, "I must notice also that because of this great cold, fire does not burn so brightly, nor give out so much heat as usual, nor does it cook food so effectually." So far as I know this is the earliest record of a fact on which Humboldt and many others have later written most interestingly. It is another proof of our Traveler's keen observation.

*Manufacture of Pygmies and Mermaids:* On their trip around southeastern Asia with Arghun Khan's envoys and the Lady Kokachin, the Polos visited Java and our Herodotus gives this interesting statement about the manufacture of pygmies. It is found in Book iii, Chapter ix (Vol. ii, pp. 285–286).

> I may tell you moreover that when people bring home pygmies which they allege to come from India, 'tis all a lie and a cheat. For those little men, as they call them, are manufactured on this Island, and I will tell you how. You see there is on the Island a kind of monkey which is very small, and has a face just like a man's. They take these, and pluck out all the hair except the hair of the beard and on the breast, and then they dry them and stuff them and daub them with saffron and other things until they look like men. But you see it is all a cheat; for nowhere in India nor anywhere else in the world were there ever men seen so small as these pretended pygmies.

These pygmies I suggest are the forerunners of the "mermaids" of later times, the manufacture of which was at one time carried on in the seaports of southeastern Asia. The late Dr. F. A. Lucas once told me that in his early voyages to China, Indo-China, Sumatra, and Java (in the middle sixties of the last century) these mermaids were on sale in these ports and that many ship captains brought home specimens. Indeed once in a space of three years two specimens were brought to my office in the American Museum. These "genuine" fabricated mermaids were made by grafting on to the torso of a small dried monkey the tail of a dried fish. Scales were so skilfully introduced among the hairs and hairs among the scales, that on one specimen it was difficult to say where monkey left off and fish began. One of the specimens referred to was so perfect and its owner was so solid in his belief that it was a natural and not an artificial product and hence priceless, that he was all broken up when I demonstrated the facts to him. I may add that it was Dr. Lucas' opinion also that Marco Polo's pygmies were the forerunners of the modern "mermaid."

This article grows long, but there are still left many things that one would like to mention. Then there is opportunity for a most interesting article on his "firsts"—first mention of this or that—a few of which will be mentioned. Thus he is probably the first to make mention of ancient astronomical instruments when he speaks of "a kind of astrolabe on which are inscribed the planetary signs, the hours and critical points of the whole year" found in the city of Cambaluc (Pekin).

Again when sailing around the island of "Seilan," Marco saw and described the fishing for pearls in the gulf of "Bettelar." And he does not fail to make mention of "those men who charm the great fishes [sharks], to prevent them from injuring the divers." This I believe to be the first mention of the men of this profession, who still make incantations to protect the pearl-divers of the present day in these same waters.

Strabo and many later writers tell us of the Ichthyophagi at the head of the Persian Gulf. Furthermore, some of these tell us that there the cattle also feed on fishes, but Marco is the first (and I believe the only one) to state that "The cattle will also readily eat these fish alive and just out of the water."

That babies are sometimes born with tails (prolongations of the spinal column) are facts well known to medical men and surgeons. There are nearly 100 cases on record in the medical literature. But whether there are races of tailed men is another matter, and one of great interest to physical anthropologists, for since the days of Ptolemy and Ctesias, they have been alleged to dwell in southeastern Asia, in the East Indies and in Melanesia. I do not know if the Herodotus of classical times tells of them, but his medieval successor does. These he heard of in the kingdom of Lambri (on Sumatra).

Some time and labor have been spent in the preparation of this article, but much has been learned and if the reading of these notes will incite others to read and study and learn from this magnificently scholarly edition by Yule and Cordier of the marvels seen and reported by our old Traveler, my labor will have been well spent.

# AMPHICEPHALOUS REPTILES

## ANIMALS REPUTED TO HAVE A HEAD AT EACH END OF THE BODY[1]

By Professor BERT CUNNINGHAM

PROFESSOR OF BIOLOGY, DUKE UNIVERSITY

MONSTERS, animals having abnormalities, have always held a strange fascination for man. Those occurring among lower animals have been the source of much of our mythology, while those occurring among humans have given rise to some of our demonology.

While there are many authentic monsters of strange and bizarre appearance, many others are figments of the imagination which are either remotely based upon fact or are wholly without foundation. It is difficult to determine the origin of some of the ideas, and their wide-spread appearance seems to argue against a common source.

Among recurring stories concerning reptiles is one which portrays animals with two heads, one at each end of the body. In this paper such animals are called amphicephala. It is my purpose to examine such reports and to determine, if possible, their bases.

Animals of the foregoing type, whether mythical or not, were early called by the group name Amphisbaena, and stories concerning them range from the days of Nicander (185–135 B.C.) to recent times, and in regions as widely separated as Europe, Asia, Africa and Mexico, and also the United States. However, it is doubtful if any modern scientist believes in the existence of such monsters.

If one were forced to select animals in which such phenomena might occur, one would most naturally select worms and snakes, and it is here, for the most part, that one finds such records and traditions. Except for a single mention of the condition in worms, the reports thus far found center upon the reptiles and include three of the four common orders of reptiles, namely, serpents, lizards and turtles.

### SNAKES

It is not at all surprising that most of the reports of amphicephalic animals, or animals that closely approach this condition, should relate to reptiles, since among them are two groups of animals without legs which have certain characteristic habits that lend aid to the deception on which such ideas may be based. There are certain snakes (*Cylindrophis rufus* and others) which are described and figured (see Fig. 1) by Barbour[2] as running with the tail erect, and, in some cases, swaying it back and forth. Such specimens would serve as exceptional evidence, to the superficial observer, of a snake which seems to be crawling backwards. It follows naturally, therefore, that this snake is capable of crawling in both directions, and amphicephala are thus created from misinformation. There are also legless lizards whose bodies are nearly uniform in diameter throughout the whole length and whose eyes and mouths are very inconspicuous. These lizards move with celerity either backward or forward and often run with the tail erected, which give them somewhat of the appearance of snakes crawling with heads raised from the ground. The general character of this group of animals may be better understood by examining Fig. 2, which is a photographic copy of the drawing

[1] The writer is especially indebted to Dr. E. W. Gudger, of the American Museum of Natural History, for many helpful suggestions during the preparation of this paper.

[2] T. Barbour, "Reptiles and Amphibians." Op. p. 48. Boston. 1926.

of *Amphisbaena alba* from Leunis.[3] To lizards of this group the name Amphisbaena has been applied in modern literature, and, in order to avoid confusion, it is proposed in this paper to use the word Amphicephala to indicate specimens which are presumed to have a head at each end of the body. This term was used by Galen in describing Amphisbaena, which was thought by him, as well as by Nicander, to be amphicephalous.

Nicander,[4] in so far as I have been able to discover, is among the first, if not the first, to describe an amphicephalous reptile. In the original Greek he uses the term "amphicarenus," which likewise means "having a head at each end." He writes (verse 372 *f*) as follows:

You find the amphisbaena to be small and slow, with a head at each end, always dim in its vision, for a blunt (or rounded) chin is extended out over the eyes at each end. The color is, as it were, of the earth, with a skin of changeful hue, spotted all over. When it comes to maturity, the wood-cutters of the mountains, after cutting a branch of wild olive as a staff, strip off the skin of the amphisbaena when it makes its first appearance, before the cry of the cuckoo in spring. The skin benefits those who suffer from numbness in their hands when bitten by the frost and icy cold, or those who suffer from exhaustion when tense nerves are relaxed and fingers grow weary.[5]

The comment on this passage in the Scholia (p. 30) is as follows:

The amphisbaena is a small and sluggish snake with a head at each end, and dim-sighted on account of the thickness of its chins. In color it is earthy, variegated with small spots. Whenever the wood cutters come upon and kill this snake, they put the skin around a staff and dry it and keep it as a remedy for fatigue and for numbness from colds.

The "chins" evidently are small folds of skin on the front of the head, which may be seen in Fig. 2. With these descriptions, one has no difficulty in recognizing the animal as an amphisbaena, and also that it is in no sense amphicephalous.

Although Nicander was a toxicologist of recognized repute, he attributed no evil effects to the presence of these animals. In time, however, the Amphicephala began to acquire a bad reputation, so much so that when Pliny[6] wrote, he described them as follows:

The amphisbaena (Amphicephala) has two heads, that is to say, it has a second one at the tail, as if one mouth were too little to discharge all its venom.

In Book 5, he cites further dangers of this reptile, but luckily suggests methods by which disastrous results may be avoided He writes:

If a pregnant woman step over a viper, she will be sure to miscarry; the same, too, in the case of Amphisbaena, but only when it is dead. If, however, a woman carries about her a live amphisbaena in a box, she may step over one with impunity, even though it (presumably the Amphisbaena) be dead. An Amphisbaena preserved for the purpose will insure an easy delivery. It is truly a marvelous fact, but if a pregnant woman steps over one of these serpents that has not been preserved, it will be perfectly harmless provided she immediately step over another that has been preserved.

The reputation of this reptile must have reached a peak with Pliny, for although Lucan (30–65 A.D.), in his "Pharsalia," clearly states the existence of the creature, he does not dwell upon its deadliness at any length. The editor's (Hoskins') note on line 719 reads:

deadly amphisbaena tapering to two heads, i.e., it was supposed to have a head at each end of its body and so be able to move equally in both directions.

Two hundred years later, Aelianus[7]

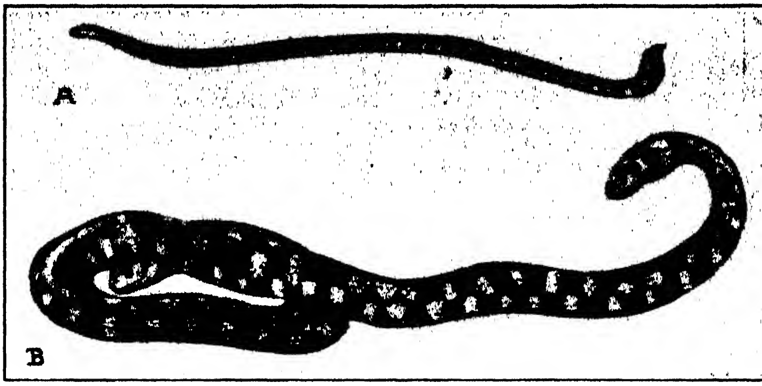
[3] J. Leunis, "Synopsis der Thierkunde," 3rd ed., Vol. 1, p. 571, Fig. 430. 1883.

[4] O. Schneider, "Nicandrea Theriaca et Alexipharmaca." Lipsiae. 1856.

[5] Translation by Dr. C. W. Peppler, Greek Department, Duke University.

[6] Pliny, "Natural History." Translation by Bostock and Riley. Bk. 8, Chap. 35.

[7] Claudius Aelianus, 250 A.D. (circ) "De Natura Animalium." Bk. 16, Chap. 47; Bk. 9, Chap. 22.




*After Barbour, 1926.*

FIG. 1. A. PHOTOGRAPH OF A SNAKE RUNNING WITH TAIL ERECTED.
B. PHOTOGRAPH OF THE SAME SNAKE AT REST.

REPRODUCED BY PERMISSION OF PUBLISHER.

places amphicephalous animals among the fabulous creatures. The idea, however, that amphicephalous animals exist was hard to destroy, and, evidently during the middle ages, as shown above, it again gained ascendency.

In 1536 Cube[8] presented a figure, presumably of this type of animal. His drawing is presented here as Fig. 3. It is rather difficult to determine whether this is really meant to be a figure of an amphicephalon or two separate snake-like animals, with closely applied tails. However, since it is an insert alongside the description of amphisbaena, one may assume it is meant to illustrate the phenomenon. The author does not claim to have seen any specimens, and he refers to descriptions by Isidore, Pliny and Jorath. The latter (an Oriental of the twelfth century whose writings seem to have disappeared), among other things, according to Cube, says: "The amphisbaena . . . is watchful and careful about its eggs, especially when incubating them. For, while one part of it sleeps,

[8] J. von Cube, 1536. Hortus Sanitatis, Quatuor Libris. Argentorati. (N.B. The first edition which appeared in 1517 has not been accessible).

*After Leunis, 1883.*

FIG. 2. THE WORM-LIZARD, *AMPHISBAENA ALBA*

THIS IS A LEGLESS LIZARD AND IS THE TYPE OF ANIMAL MEANT BY THE MODERN WRITER WHEN HE REFERS TO AMPHISBAENA.

*After Cube, 1536.*

FIG. 3. EARLY FIGURE OF AN AMPHICEPHALIC ANIMAL

THIS IS PRESUMABLY A SNAKE, AND IS PROBABLY THE OLDEST FIGURE OF THIS PHENOMENON.

the other keeps watch." The similarity of this figure to the one produced by Hernandez (see Fig. 5), who quotes a statement similar to the above, may suggest the source of the Hernandez figure.

The reports of this type of animal reached the climax during the seventeenth century, and, as usual, two schools were formed—those who believed and those who denied. Weird tales were brought in by many explorers, and mention of such monsters is made in many of the standard books of travel. Fabri[9] not only believed in the occurrence, but thought they represent a distinct species. He says:

amphisbaena, a little beast . . . For what exceeds the limit of nature and the rank and file of created things than to paint or even fashion, much less to behold a living animal with two heads—not in one place, a thing seen sufficiently often in monstrosities, but one where the tail usually is, and this is not fortuitous either through fault of a sporting or erring mother nature, or in a joke, but by a serious plan in that in the entire species of animal it is accustomed to happen; a thing which most serious authors maintain happens in the amphisbaena.

Fabri does not attempt to figure the monster, but does append a figure of the true Amphisbaena from Paris, which most certainly does not show a head at each end of the body, as may be seen from our Fig. 4.

Although Hernandez[10] did not believe in amphicephalic snakes, he thinks that he should describe a form of which he had heard through a friend. The latter had in his possession a drawing done in color of an amphicephalous reptile which he said had been given him by a man who had made the drawing from a specimen which apparently had originated in Mexico. The figure from Hernandez' text is reproduced here as Fig. 5. From it one is unable to locate this specimen in any order of reptiles. Hernandez thinks that these animals are mythical;

[9] J. Fabri, "Animalia Mexicana," p. 729. Rome, 1628.

[10] A. F. Hernandez, "Nova Plantarum Animalium et Mineralium Mexicanorum Historia." Rome, 1651.

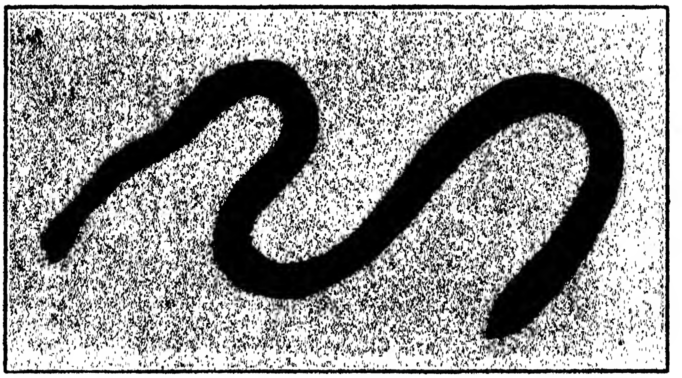


FIG. 4. AMPHISBAENA ACCORDING TO FABRI (1628)

THIS CERTAINLY DOES NOT APPEAR TO BE AN AMPHICEPHALON.

however, he notes that the "Hortus Sanitatis" says that Amphicephala incubate their eggs and that the two heads take their turn in keeping watch over them.

Browne,[11] who seeks to destroy all error, finds the reports hard to believe, and finally says that if such monsters do occur, "they are beside the intentions of nature."

Vernatti,[12] in reply to an inquiry concerning the occurrence of these creatures, writes:

There are indeed such serpents in these parts (Java Major) which have a head at each end of the body, called Capracapella. They are esteemed sacred by these people, and fortunate to those in whose houses and lands they are found, but pernicious to whomsoever doth harm them. I would have sent one but could get no man who would kill one of them.

Herrera,[13] describing the animals of the new world, states:

The rattlesnakes are very poisonous as are those having two mouths, the one at the head and the other at the tail, and bite with both; they are white and very short, and persons that are bit by them live only a few hours.

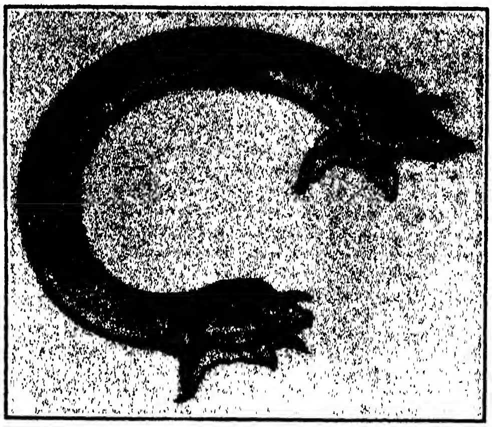
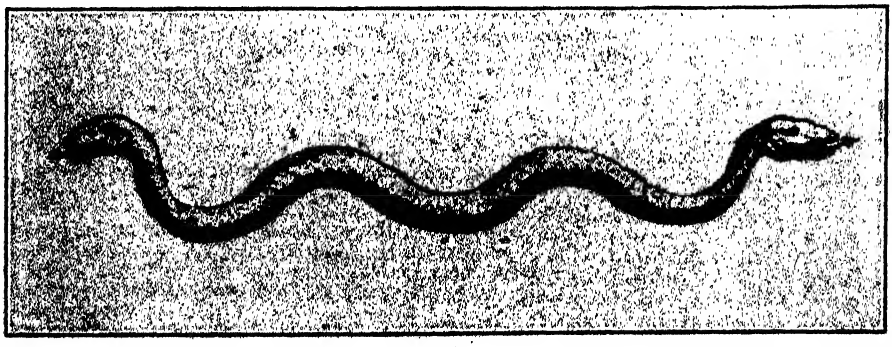


FIG. 5. HERNANDEZ' AMPHISBAENA (AMPHICEPHALON)—1651

THIS FIGURE PURPORTS TO HAVE BEEN DRAWN FROM A LIVING SPECIMEN FROM MEXICO.

Thus far the stories concerning serpents have been hearsay, and apparently none of the foregoing have been eyewitnesses of this type of monster. However, in 1679, a catalog of the Swammerdam[14] collection was published, in which, among other curious creatures, was listed an *Amphisbaena serpens*. In the following year, Blancartus[15] commented on this specimen as follows:



*After Blancartus, 1680.*

FIG. 6. SWAMMERDAM'S AMPHICEPHALON

THIS SPECIMEN IS SAID TO HAVE BELONGED TO THE COLLECTION OF SWAMMERDAM IN AMSTERDAM.

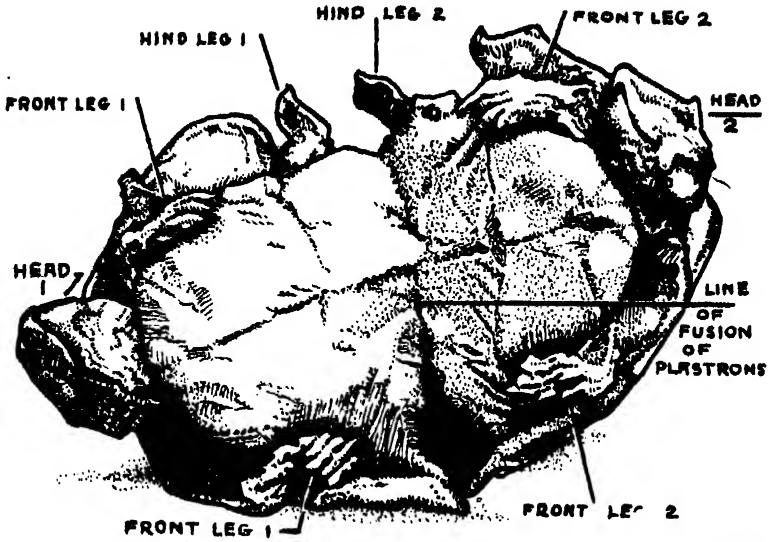
[11] Sir Thomas Browne, "Pseudoxie Epidemica." London, 1669.

[12] Sir Philip Vernatti. "Answer 5. Philosophical Transactions, giving some account of the present undertakings, studies and labors of the ingenious in many considerable parts of the world." Vol. 3, p. 863, 1667.

[13] Antonio de Herrera y Tordesillas, "The General History of the Vast Continent and Islands of America, commonly called the West Indies, from the First Discovery thereof." Translation by John Stevens. Vol. 4; p. 97. London, 1725–1726.

[14] Jan Swammerdam, "Catalogus Musei exhibens curiosam suppellectilem variarum rerum exotic." P. 37, Amstelodami, 1679.

[15] B. S. Blancartus, (Blankaart), Observation 20. Collectanea Medico-Physica, Oft Holland Jaar-Register Der Genees-en Natuur-




*After Townsend, 1928.*

FIG. 7. A TURTLE WHICH APPROACHES AMPHICEPHALY

TWO TURTLES FUSED POSTERIORLY, WITH TAIL LACKING. REDRAWN FROM HALF-TONE FIGURE IN THE BULLETIN OF THE N. Y. ZOOLOGICAL SOCIETY.

Some may not believe in two-headed snakes, but they do actually exist, for I have actually handled one which is among the Swammerdam rarities. The specimen is a span and a half long, normal in color, and has a head on each end of the body with small scales.

The figure which accompanied his report is reproduced herewith as Fig. 6. There can be no doubt about what he aims to show. This case is of exceedingly great interest, since two reputable scientists and a well-known scientific publication are involved. Furthermore, if this specimen did actually exist, it must stand alone, as no other cases of exactly this type have been found in the considerable literature that has been examined.

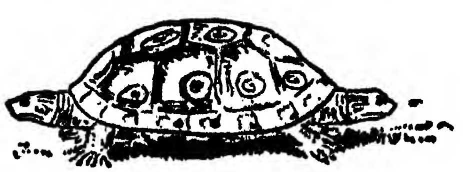


FIG. 8. A DOUBLE TURTLE

A TWO-HEADED TURTLE ERRONEOUSLY FIGURED AS AMPHICEPHALIC, BY ROBERT RIPLEY IN HIS SYNDICATED NEWSPAPER COLUMN "BELIEVE IT OR NOT," 1931.

Taken as a whole, it would seem that all the cases reported in reptiles, with the exception of Blancartus, might easily be explained upon some other basis, and, since in no case are they observations of eye-witnesses, they may at least be held in grave doubt, if not totally rejected. The case of Blancartus, on the other hand, must be considered, since an actual specimen in the collection of a scientist, observed by a scientist, and recorded in a scientific publication, can not be ignored, even though one is justified in wishing for additional confirmation.

## TURTLES

The occurrence of amphicephalous monsters is not incredible. Twins, among humans, have been found fused together in almost every conceivable position, and, among turtles, a case has been reported which approaches, although it does not parallel, the condition described by Blancartus for the snakes. Townsend[16] has figured a pair of

kundige Aanmerikingen vangantsch Europa. Cent. 1, p. 29, fig. 68. Amsterdam, 1680.

[16] C. H. Townsend, "A Double Turtle." *N. Y. Zool. Soc.* 31: 35–36, 4 figs. 1928.

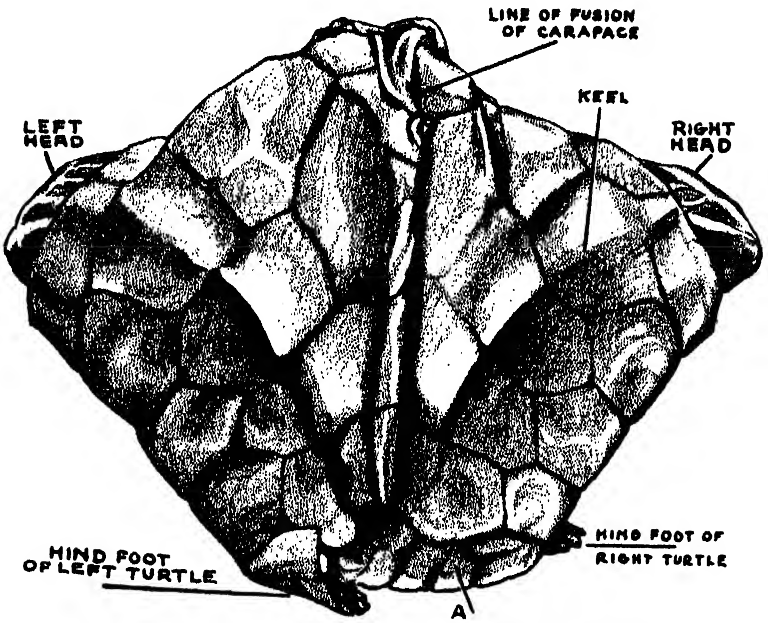



FIG. 9. A STRANGELY MALFORMED TURTLE

DORSAL VIEW OF THE CARAPACE OF THE MONSTER SHOWN IN FIG. 8 DRAWN FROM THE PHOTOGRAPH. ORIGINAL DRAWING.

turtles which were fused together at the posterior ends of the carapace. This figure is reproduced here as Fig. 7. If the two posterior ends of the serpent twins should become grafted in a similar manner but with a little more efficiency, just such a condition as that described by Blancartus would arise. Such an animal might well grow to hatching size, be hatched and live for a few days, even in the complete absence of an anus. The occurrence would naturally be exceedingly rare, possibly even more so than our present records indicate.

It is unfortunate that this specimen figured by Townsend is not available for x-raying, since that would determine whether or not the fusion extended to the skeletal structures.

There recently occurred a figure in Ripley's "Believe it or Not," of a reputed amphicephalous turtle in the possession of a citizen of this state (North Carolina), which is reproduced here as Fig. 8. The source of the "information" on which this figure is constructed is unknown, but the owner of the specimen, who unfortunately had

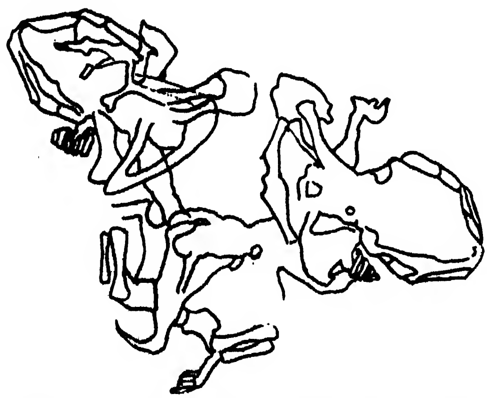


FIG. 10. OUTLINE DRAWING OF X-RAY OF MALFORMED TURTLE

THE TWO VERTEBRAL COLUMNS, TWO SKULLS, SIX LEGS, TWO SETS OF RIBS, AND THE TWO PECTORAL GIRDLES ARE QUITE EVIDENT. THE PELVIC GIRDLE APPEARS SINGLE BUT SLIGHTLY MALFORMED. DRAWN FROM A PHOTOGRAPH BY THE X-RAY DEPARTMENT OF DUKE UNIVERSITY MEDICAL SCHOOL. SAME SPECIMEN AS FIG. 9. ORIGINAL DRAWING.

loaned it to a show, when shown this picture, wrote me as follows:

What was in the paper was not right. The animal is about the size of a dollar, has two heads, six legs and two tails.

Later I have been able to recover the specimen and, although it is considerably the worse for wear, I have been able to study the carapace, plastron and skeletal structure. The internal organs were not studied, as external examination indicated that they had probably disintegrated.

The specimen was taken alive by Mr. H. E. Haithcock on a creek bank near Cedar Falls, N. C., in the latter part of January, 1931. It was kept alive until the following June, when it was given into the custody of a traveling show. Some time between then and January, 1932, the animal died and was preserved.

The specimen had evidently hatched during the preceding season and was probably undersized, as it is considerably smaller than the newly hatched specimens of turtles. The measurement from tip of snouts is a little less than four cm. The other proportions are evident in the drawings.

The heads are almost diametrically opposed (see Fig. 9), as figured by Ripley, but in every other detail his figure is erroneous. The tails lie in a line almost perpendicular to the two heads. This has been brought about by a curvature of the vertebral columns. The base of the tail appears single in the external view while the posterior end is branched. The x-ray, however, reveals the true structure. There are two separate tails, in so far as caudal vertebrae are concerned, which cross each other, forming an X. In Fig. 10 an outline drawing of the bony structures is presented, based upon x-ray photographs. While the forelegs of both animals seem to be normal in structure and in number, each animal has but a single hind leg. From the x-ray, it also appears that the fusion is in the pelvic region and that the inner hind legs are eliminated in both specimens. The outer hind legs which are present seem to be normal as to structure.

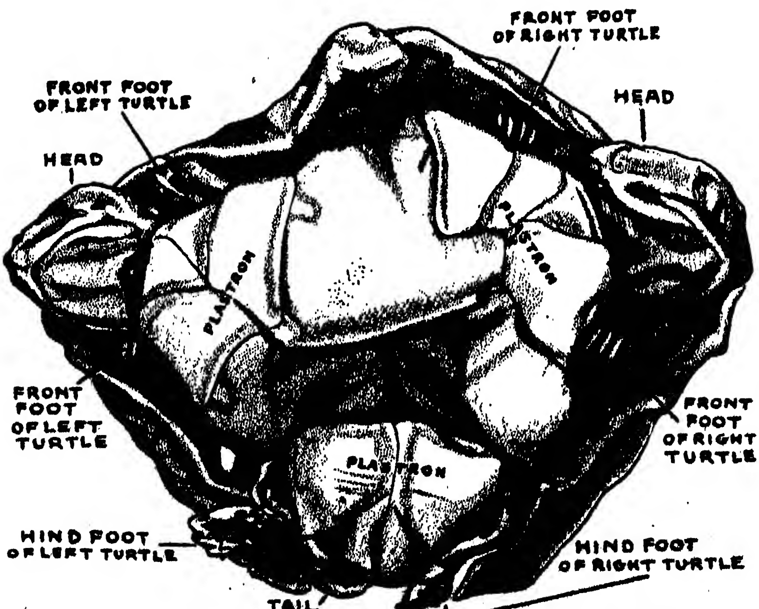



FIG. 11. VENTRAL VIEW OF MALFORMED TURTLE

SAME SPECIMEN AS SHOWN IN FIG. 9, DRAWN FROM PHOTOGRAPH. ORIGINAL DRAWING.

*After Aldrovandi, 1637.*

FIG. 12. VIEW OF A TWO-BODIED, TWO-HEADED LIZARD

DESCRIBED AND FIGURED BY TORQUATUS BEMBUS. PHOTOGRAPH THROUGH THE COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

The carapaces are fused rather roughly in places (see Fig. 9), and a sub-carapace (A) is formed in the tail region, which is overlaid by the usual carapace, much in the fashion of shingles. The plastrons (see Fig. 11) in the head regions are somewhat normal, and the posterior end has a single plastron placed nearly at right angles to the axis of the two heads.

Because of the extremely deteriorated condition of the interior, no effort has been made to get structures other than skeletal, but it seems reasonable to suppose that for the most part each animal has the usual quota of viscera, except possibly in the pelvic region. The presence of two tails might be an evidence that even here the alimentary canal and sex organs may have been separate. These data indicate that this specimen should possibly not be included among the amphicephala.

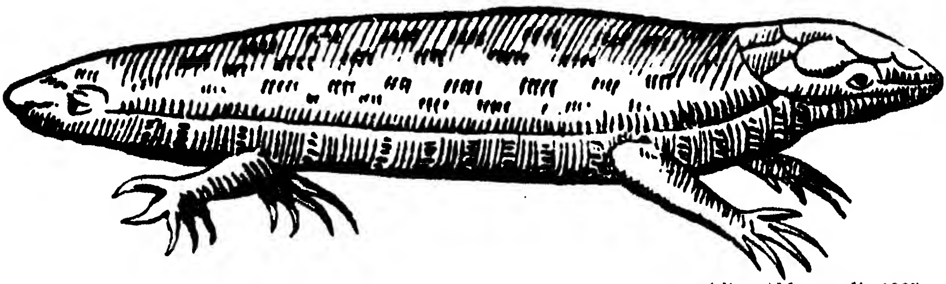
With the possible exception of the case reported by Townsend there does not seem to be any clear-cut case of amphicephaly in the turtles. Whether Townsend's case is good depends, it would seem, upon the degree to which the structures became common to the two specimens—a point which is not clear either from his photographs or descriptions.

### LIZARDS

So far as I have been able to discover, the two lone cases of amphicephalous lizards are presented by Aldrovandi;[17] one of which he reports from another source; the second came under his own observation. Both specimens are here figured.

The first of Aldrovandi's figures is taken from an earlier work by Torquatus Bembus, and represents two lizards with the bodies fused, the heads pointing in opposite directions (see Fig. 12). It does not seem reasonable to call this animal an amphisbaena (or amphicephala) as has been done by Bembus. There is nothing to indicate that these are any more than very simple Siamese twins, fused in an unusual fashion, to be sure, but quite probably without any of the internal organs in common, a thing which would not be so incredible as that shown in his second figure (see Fig. 13), where it seems evident that the two bodies are fused end to end in what should be about the middle region of each animal. In this latter he does not say whether or not an anus is present. The animal was alive when taken, and "walked in the direction of each head."

[17] Ulyssis Aldrovandi, "De Quadrupedibus Digitatis Viviparis. Monstra," p. 639. Bononiae, 1637.



*After Aldrovandi, 1637.*

FIG. 13. AN AMPHICEPHALIC LIZARD

DRAWN FROM LIFE BY ALDROVANDI. PHOTOGRAPH THROUGH THE COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

The figure is said to have been drawn from the living specimen.

Since Aldrovandi claims to have seen this specimen while it was living, and also made the figure from the living animal, one can not do otherwise than accept it. This provides, therefore, a good case of amphicephaly among lizards.

## POSSIBLE SOURCE OF TRADITIONAL CASES

Since this monstrosity is so uncommon, and since the stories, especially those concerning snakes, are so wide-spread, it is unreasonable to suppose that all the stories of Amphicephala have originated from the actual observation of an amphicephalous type of monster. There are other ways in which this idea may have originated concerning serpents. The credulous may have been fooled by the native Hindu who paints eyes and a mouth on the posterior end of the rubber boa to give it the appearance of being amphicephalic; or by the same treatment accorded the Gila monster by natives. In some cases even artificial decoration is unnecessary, for Ditmars[18] writes as follows:

> The Brown Sand Boa *Eryx johnii* . . . owing to its stubby tail is also called the two headed snake, and, when coiled in a mass with the head hidden and the tail protruding as is a common position, the tail might readily be mistaken for the anterior end.

It also seems quite possible that the idea may have originated from snakes similar to those described by Barbour (*l. c.*). If one, unaware of the habit, should see such an animal crawling with the tail erected, one would immediately conclude the animal was running backward. From that point it is not far to the conclusion that the animal has a head on each end of the body. In animals so spectacularly marked as those shown by Barbour, the deception would be complete.

[18] R. L. Ditmars, "Snakes of the World," p. 35. New York, 1931.

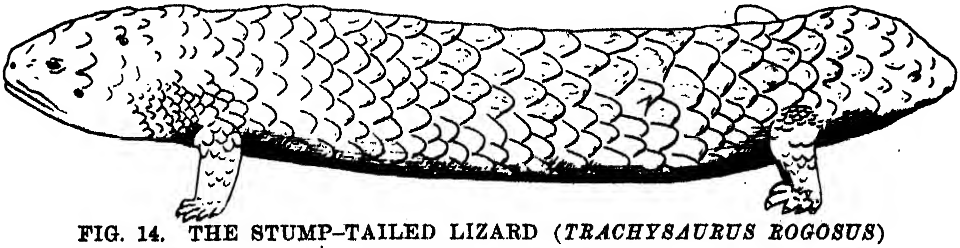


FIG. 14. THE STUMP-TAILED LIZARD (*TRACHYSAURUS ROGOSUS*)

REDRAWN FROM PHOTOGRAPHIC HALF-TONE IN THE BOOK OF POPULAR SCIENCE. BY PERMISSION OF THE PUBLISHER, 1928.

Another source of the idea is made evident by Hawley,[19] who related the following experience:

A few days ago a collection of animals belonging to Mrs. Wombwell made a short stay in this town [Doncaster], and the proprietress circulated handbills describing, among other novelties, a group of *double headed snakes*, a portion of one of which I enclose. Of course, the announcement of so extraordinary an anomaly aroused my curiosity, and I went to see this strange reptile with, to use the words of the keeper in describing it, a head at each extremity of the body, the scales running both ways toward the middle where the vent is situated. I endeavored, but in vain, to obtain a close inspection. The reptiles were kept in a tin box and when exhibited the lid was opened, a quantity of old furs taken out, and one of them was seized by the middle with a long pair of tongs and thus held writhing over the heads of the spectators. The one I saw was just shedding its skin, and parts of the body from which it had separated were dark brown and moist looking. Both extremities were thick and rounded, and from one I distinctly saw a tongue protrude several times; the other was much obscured by fragments of old skin, which the keeper declared, covered another head; but, from the manner in which the reptile was held up, and the respectful distance we were compelled to maintain, it was impossible to determine satisfactorily whether he spoke the truth or not. My own conviction is that the double head is, at most, apparent. If I am right, I think it very proper that such an attempt to impose on the credulity of the public should be exposed; if I am wrong, creatures so extraordinary should certainly not be suffered to remain inmates of a traveling menagerie. I may mention that the keeper related fearful instances of their deadly venom. A young rattlesnake bitten by one of them died in three minutes; a sparrow was swelled in a short time by the poison to the size of a pigeon.

[19] J. R. Hawley, "Snakes with Two Heads." *The Zoologist*, 11: 4153. 1853.

More likely, however, the early ideas originated from a group of legless lizards which, in modern times, have received the name of *Amphisbaena*. These animals, although lizards, appear as snakes because of their legless condition. The bodies are nearly the same diameter throughout, and it is with difficulty that one is able to determine the anterior and posterior ends. Add to this the fact that the animal moves with facility forward or backward, and you have the foundation for the story. The French aptly call these animals "double-marchers." See Fig. 2.

Except for the fact that Aldrovandi specifically states that he observed the lizard specimen, his figure might well have originated from a more or less careless observation of some such animal as the stump-tailed lizards, which appears depicted in Fig. 14, redrawn from an original photograph of the animal published in the "Book of Popular Science."[20] This particular form is a native of Australia.

It is evident that many of the reported cases are based upon hearsay, and that others may be based upon misinterpretation, but, nevertheless, that there are a few cases in which the actuality of existence can not well be doubted must be conceded. It is reasonable, therefore, to conclude that amphicephaly does occur in reptiles, but that it is exceedingly rare.

[20] Book of Popular Science. Vol. xii, p. 4062. By permission. Grolier Soc. (N. Y.) 1928.

# MOSQUITO CONTROL ON HYDRO-ELECTRIC PROJECTS

By EDGAR E. FOSTER
CIVIL ENGINEER, MONTGOMERY, ALABAMA

When you turn on your electric lights at home, it may seem that your act has nothing in common with malaria. Yet, in the Southern states, a connection exists, for if you live closely enough to the source you may get both from the same reservoir, unless the power company has taken adequate means to suppress your buzzing nocturnal visitors. If your residence is within flight range of these mosquitoes singing about your head, they may have been hatched in the reservoir created by the dam at which your electricity was generated. However, it is more probable that the engineers of the power company and the public health commissioners have foreseen this problem and have taken adequate steps to prevent the maturing of any dangerous numbers of mosquitoes.

In the creating of any artificial lake as a reservoir for a hydroelectric project, it is always desirable to clear the area to be flooded of all trees and brush which may project above the water surface. However, in the southern parts of the United States and in other parts of the world having tropical and warm temperate climates, such clearing is more than desirable; it is virtually a necessity on account of the sanitary considerations involved. It is always desirable from an esthetic view-point to clear such reservoirs completely; and usually there is some merchantable timber which should be removed for economic reasons. In any case clearing greatly improves

PART OF A RESERVOIR IN A CYPRESS SWAMP

Brush and small trees have been cut out to permit easy dusting. Water is at normal elevation.

A RESERVOIR IN A CYPRESS SWAMP
THE BACKGROUND SHOWS TREES, BRUSH AND UNDERGROWTH IN THE NATURAL STATE.

the reservoirs for recreational purposes, such as fishing and boating. However, it is doubtful if all these reasons would justify the cost if it were not necessary for protection of health of the community.

There are a number of serious diseases which are known to be disseminated by various species of mosquitoes. The best known is probably yellow fever; which is spread by the mosquito now called *Aedes calopus.* Although this mosquito is still common in this country, the disease has been stamped out and no longer forms a problem for sanitary engineers. Dengue and filariasis are mosquito-borne diseases that are more commonly found in the tropics and sub-tropics than in the United States, although some cases are occasionally reported here. These two diseases are believed to be conveyed by the mosquito, *Culex fastigans,* with perhaps some other species assisting in the spread of filariasis. However, the *Culex fastigans* and the *Aedes calopus* are domestic mosquitoes—that is, they breed close to human habitation and hence are not a part of the problem of sanitary control on hydroelectric projects. Just the reverse is true of the mosquitoes of the genus Anopheles, which transmits the wide-spread and serious disease, malaria. This genus of mosquitoes necessitates the expenditure of much effort and money to make possible the large hydroelectric projects in the South without impairing the health of the inhabitants of the adjacent regions.

Health is the most urgent reason for clearing reservoirs in all southern parts of the United States on account of the presence of malaria in the human population and the existence of the malaria-carrying mosquito. In this section there is no other disease that may be spread by the creation of artificial lakes or ponds, so that the health problem connected with such waters is reduced to the prevention of this disease.

It is now well established that malaria is transmitted from an infected person to a healthy one by the species of one genus of mosquitoes, that is, the Anopheles. In the southern part of the United States, it is mainly the *Anopheles quadrimaculatus.* There are two other species of lesser sanitary importance in the same region, *Anopheles punctipennis* and *Anopheles crucians.*

West of the Rocky Mountains, malaria is spread by still another species and in other parts of the world still other species, all of the same genus, are the carriers. In the south Atlantic and east Gulf tiers of states, however, the *Anopheles quadrimaculatus* is the worst offender, and it is against this species that the efforts of control have been directed on those lakes under the writer's observation.

The Anopheles are a swamp-breeding mosquito, preferring fresh, clean, still water in protected habitats. Suitable protection may be furnished by grass or other hydrophytic vegetation, floating twigs, chips and detritus from decaying timber. They are night flyers, that is, most of their flying is done late in the evening or after dark. During the day they hide in dark corners of buildings, or any sheltered place away from light, and emerge at night. Their maximum range of flight is usually not over one mile, although on their first trip they may go farther, but on that trip they are not infected and hence can not carry malaria. All these facts are important, and on them are based various means of combatting the Anopheles.

The female Anopheles lays her eggs in still pools of water where the eggs and larvae will find protection from their natural enemies. She prefers clear fresh water and rarely deposits eggs in that which is brackish or foul and selects places in swamps or pools where the water is still or moving very slowly. The need for protection is satisfied by grass or other hydrophytic plants, or by floating debris, especially fine stuff which will enable the larvae to hide from small fish and other enemies. The larvae feed largely upon minute forms of green algae which grow most abundantly in the same vegetation and debris that furnishes their protection. These larvae are usually found at or near the surface of the water and floating in a horizontal position; they often appear to be on the surface.

The natural enemies of the Anopheles which are most effective in reducing the numbers of mosquitoes and hence most useful in control work are species of small top-feeding fish or minnows which

A RESERVOIR IN A CYPRESS SWAMP

THE UNDERGROWTH IS CLEARED OUT ON THE EXTREME RIGHT BUT NOT IN THE CENTER.

THE UNDERGROWTH

IN THIS CYPRESS SWAMP RESERVOIR HAS BEEN CLEARED OUT TO PERMIT ACCESS BY BOAT FOR DUSTING WITH PARIS GREEN.

prey upon the larvae. The best known species in the South is the *Gambusia affinis.* Another important fish is the killifish (Fundulus) whose habitat ranges farther north than the Gambusia but has not been used under the writer's observation for control of mosquitoes on hydroelectric reservoirs as the Gambusia has been. The *Gambusia affinis* is a small minnow ranging in size from about one to two inches in length. It is found in fresh or brackish water and will live in foul water. It is a surface feeding minnow, which fact gives it its great value in destroying mosquitoes, especially the Anopheles. Being small it can swim freely among the larger plants and trees and large debris and logs, but small plants, as grass, rice, and pond lilies, will obstruct its movements and prevent it from finding its prey, such as the larvae of the mosquitoes.

In the usual form of warfare against the mosquito, drainage of all possible ponds, pools and swamps near human habitation is the regular procedure. This eliminates the malaria-carrying mosquito, as well as all others, at once by the destruction of its breeding places. However, in the construction of hydroelectric projects that method is out of consideration, for indeed the opposite course is followed in that the land is flooded instead of drained. Other means of carrying on the fight must therefore be sought and used.

Now in the southern part of the United States and other regions where malaria is prevalent, proper preparation of the area of artificial lakes and ponds, such as reservoirs for hydroelectric projects, for flooding must be made as the first step, or mosquito control will be very costly or even impossible. The area to be prepared varies with every project and is dependent upon the topography of the land. In a mountainous or hilly country where steep slopes are the rule, this preparation is relatively small for the reason that the head (or fall) is high, while the amount of power is large and the area to be flooded is small. In other regions, such

A BAY IN A WELL-CLEARED RESERVOIR

FLOATAGE IS ALWAYS LIKELY TO COLLECT IN SUCH BAYS AND NECESSITATES TREATMENT.

as the lower parts of the Coastal Plain, the slopes, especially on the river bottoms, are flat, and a dam with a small head will form a comparatively large lake. One project recently completed has a normal head of 34 feet and floods approximately 11,500 acres of land. In a project of this sort, the preparation of the reservoir may easily cost half as much as the dam, power plant and land and constitutes a controlling item of the total expenditure for the project.

The most satisfactory means of preparing the area of a reservoir for flooding is clearing it of all trees and brush. For all practical purposes this means clearing so that none will be visible above the water surface when it is at the lowest elevation to which it will or may be drawn for any operating purpose. Complete clearing necessitates cutting all trees and brush, leaving as short a stump as practicable, drying and burning or otherwise removing from the area to be cleared. It has not been found necessary to remove stumps, the extraction or grubbing of which would make the cost of nearly any hydroelectric project prohibitive. On low head projects, where the water in the reservoir is shallow, this condition means clearing the entire area; on projects with higher heads, the same results are obtained by clearing completely the area

A CLEARED RESERVOIR

WITH GRASSY EDGES WHICH REQUIRE REGULAR DUSTING OR OILING.

on which the ground will be exposed and on the areas under the deeper water, cutting the trees and brush and tying them down by wire to the stumps, so that they will be completely and permanently submerged. This may be done at a considerable saving in cost.

The clearing of a reservoir is essentially a lumberman's job, although there are several features that are added to the task of cutting marketable timber. All small trees and brush must be cut and all material which can not be economically transported out of the basin (and this includes a very large portion of all that is cut) must be piled and burned. This is accomplished either by cutting up large pieces so that all can be handled by manual labor or by piling it with skidding machinery. For the latter purpose tall trees are left standing here and there by the cutting crews to serve as masts to which cables run from the skidders and thence to the fallen timber scattered over the basin and drag this material into a large pile surrounding the tree mast. After drying, the pile may be burned.

Complete clearing in this manner will leave the reservoir in a very satisfactory condition for all purposes, including recreation and the later operations for control of mosquitoes. Although there will always be more or less floatage of debris from the clearing operations when the reservoir is first filled, this soon disappears and leaves a clean lake in which there will be ample wave action and a clean shore line, both of which are detrimental to the breeding of mosquitoes.

In some cases, however, the problem of clearing is not so simple. In flat regions, where only low head dams are possible, a small drop in the elevation of the surface of the water will uncover a comparatively large area of ground in the upstream parts of the reservoir. While this will be beneficial as long as the edge is clean and free from vegetation, if the water remains down for any great length, the exposed land will soon be covered by weeds, brush, willows and plants fond of wet soils. When the water rises again this growth forms an ideal habitat for mosquito larvae; the wave action is broken up; there is ample food available; and there is good protection from their natural enemies, such as the Gambusia. This alternate exposure and submergence may be caused by the drawing down of the reservoir for water to operate the power plant during a dry summer or may be caused by periodic floods or by both. Of course, lands which are submerged for periods shorter than necessary for the incubation of the eggs and growth

A CLEAN SHORE-LINE

OF A WELL-CLEARED RESERVOIR REQUIRES NO DUSTING OR OILING.

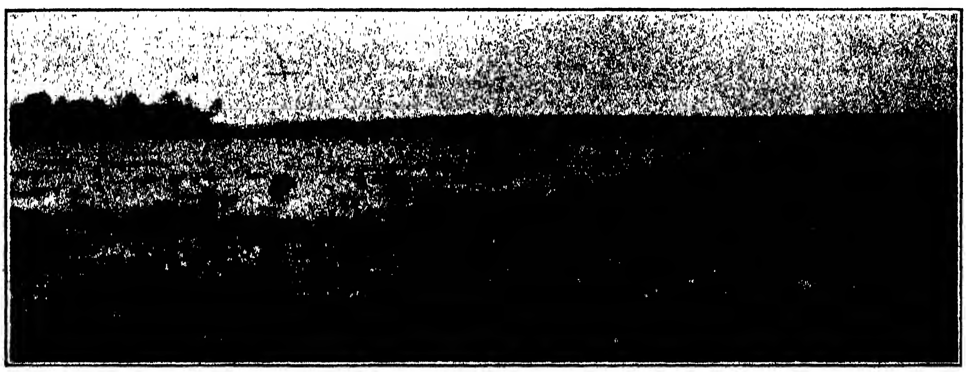
MODERN MACHINERY USED IN CLEARING OPERATIONS

THIS IS A REHAUL SKIDDER USED TO PILE LOGS FOR DRYING AND BURNING.

of the larvae form no part of the problem because there can be no successful breeding of mosquitoes on such land.

In such areas complete clearing is not desirable. Better results will be obtained by clearing only the underbrush and small trees, leaving the large trees to shade the ground and prevent the second growth of brush and other small vegetation. This course will permit the use of boats for chemical mosquito control when the area is submerged and allow free access to all isolated pools by men on foot when the water is drawn down.

In addition to clearing the area to be flooded, other schemes have been prescribed at different times for various projects. In one case, the builders were required to kill all pine trees for a distance of fifty feet from the shore-line of the reservoir. This scheme was abandoned and never put into operation. In several other cases, the project builders were required to clear above the contour of the highest elevation of the water surface for a horizontal distance of fifteen feet beyond the edge of the pond. Neither of these schemes have any effect on the mosquito problem, except that fallen leaves and pine needles may be assumed to float on the surface and form



A FAIRLY WELL-CLEARED RESERVOIR SITE

WHICH HAS BEEN PARTLY FLOODED. SOME LOGS AND LARGE FLOATAGE HAVE BEEN LEFT, BUT THESE WILL FORM NO PROTECTION FOR MOSQUITO LARVAE.

protection for the larvae; but since leaves do not fall until the season for mosquito breeding has practically ended, these schemes necessitate needless labor and cost.

After the reservoir area is cleared and the reservoir filled, continual work of mosquito control must be carried on. Cleared lakes with clean edges or shorelines greatly reduce the amount of work and cost of this control, but nevertheless some is always necessary.

Although they can not be relied upon for complete control, the top-feeding minnow, *Gambusia affinis*, is useful as an auxiliary, and they were planted in one large reservoir for that purpose. However, they are more useful in smaller ponds than usually formed by hydroelectric projects. Yet there is one such reservoir to the writer's knowledge in which the Gambusia play an important part in destroying the mosquito larvae. The reservoir of this particular project contains considerable debris of large size, trees and logs which should have been removed before filling; it is possible that this debris protects the Gambusia, which are very numerous, from larger fish which prey upon them.

For complete control—by which is meant maximum possible prevention—of mosquito breeding, dependence is placed on oil and chemicals.

The oil used in this work is a petroleum product and is usually some oil heavier than kerosene and may be a light crude oil. However, in one case it is claimed that kerosene is better on account of a supposed toxic effect on the mosquito larvae. The oil is sprayed over the surface of the water either alone by air pressure or by being mixed in water by pumps which throw a stream of the mixture as far as one hundred feet. The oil spreads over the surface of the reservoir in a thin film which prevents the larvae from breathing. For this purpose the oil should be light enough to spread well, yet heavy enough so that it will not evaporate for several days.

For chemical control, Paris green is dusted over the surface of the water and poisons the larvae of the Anopheles which eat it. The apparatus and methods used for this are similar as for oil, except that the pumps and sprays are replaced by blowers. Before using, the Paris green is mixed with a cheap inert material, such as lime or limerock dust, in order to effect a greater and more uniform spreading of the poison. This method is particularly advantageous over areas that are not well cleared or in shallow water where boats have difficulty in navigating, because even a very light breeze will carry the dust a long distance and it will filter down through rather heavy vegetation to reach the water beneath. The efficacy of this method is due entirely to the toxic action of the Paris green.

Both oil and Paris green are applied to the surface of the reservoir wherever larvae of the Anopheles may be found. The amount of material and labor required are manifestly reduced in proportion to the amount and quality of clearing done. When the flooded area has been properly cleared before the reservoir is filled, spraying is necessary only along the shore or in small bays and bights where wind and wave action will gather small floatage which will form protection for the larvae or at the mouths of creeks, the water of which may bring down larvae from the reaches above. Wherever there is a sufficient depth of water, boats are used to transport both men and material over the reservoir. For ponds and sloughs which can not be reached by boat, the men must go over the land on foot and carry their sprayer or blower and material with them.

Other methods supplementary to the

above have been suggested and in some cases carried out. One of these is the purchasing by the owners of the reservoir of all land within one mile of the shore-line and moving off this land all inhabitants. This procedure attacks the malaria problem from the human side. Since the malaria parasite must pass a phase of its existence in a human being, the removal of all such carriers from the flight radius of the Anopheles prevents the infection of that mosquito, which therefore can not transmit the disease to other human beings. Since the flight range of the Anopheles is only one mile, it is not necessary to remove the inhabitants from land which lies at any greater distance. To supplement this course a proposal has been made in one case to range cattle on land so purchased. The purpose of this is the furnishing of a source of blood for the mosquito within the one-mile limit so that they may not be compelled to fly farther and become carriers by contact with human beings.

Obviously these supplementary methods are limited to sparsely populated regions, where land values are low. However, hydroelectric projects are frequently built in just such regions and any method of reducing the expense of such costly construction without menacing the health of the people should be a general benefit to the patrons of the public utilities. The reservoir would still be suitable for recreational purposes in the daytime, since the Anopheles is a night-time flyer and hence there would be small likelihood of its infecting persons who spend a day fishing or boating. Camps which are occupied during the night should be adequately screened, however.

Assistance in control may also be obtained by fluctuating the pond level through various seasons. By raising them in the winter, the floatage is lifted to elevations and is driven back on a higher shore-line on which it will remain when the pool level is lowered. The same rise of pool level tends to kill off bank vegetation. Therefore, at the beginning of the next breeding season, the pool is lowered to a clean shore-line, free of floatage and vegetation.

Although the preparation of a reservoir for mosquito control is usually reckoned as a minor part of the construction of a hydroelectric project, you can readily see that it is no small job in itself. It requires the skill and labor of both the civil engineer and entomologist, being, in fact, one of the few grounds on which these two meet in a common task to promote and protect the health of those people in the community of the project, while others at distant places may enjoy their electric conveniences.

# HOME ECONOMICS RESEARCH BY THE FEDERAL GOVERNMENT

By Dr. LOUISE STANLEY

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THE scientific aspect of familiar things is rarely obvious to the layman, and nothing is more familiar to all the world than the daily routine of the household. This, no doubt, is largely the reason why household problems were so long neglected as subject-matter for research.

The importance of this field, however, has been forcibly demonstrated in the United States these past three years. Upon most of the 30 million homes, the depression forced some kind of readjustment. It compelled the family in most cases to count not only pennies but values—in food, clothing and household goods of all sorts, in skills and services required to carry on. Food values, especially, most vital in time of stress—who in the average family knows enough about them to cut food costs to the bone, without incurring a hazard to health?

Under pressure of this kind, if never before, the home-maker realizes her dependence upon home economics research. When a family's funds are at rock bottom, what are the best foods to buy? What will give the most for the money —the most in nutritive value? What at the minimum is an adequate food supply for a family of given size and make-up? How to protect the children on a restricted food supply? These questions call for a scientific answer, not somebody's guess or notion, or long-standing preference or habit.

The U. S. Bureau of Home Economics receives a continual stream of requests for advice and assistance with such problems; letters from individual homes, and from relief agencies; from teachers, child welfare societies, public health clinics, community service groups of all kinds. Fortunately, nutritionists have been at work on these problems for years. The bureau itself is a research agency, with its own nutrition laboratory, its own food utilization laboratory, its own specialists who are continually engaged in original research or in compiling information on the composition and uses of food. One of the major efforts of the bureau in the past three years has been to teach the public how to protect itself so far as possible when forced to live on restricted diets. Balanced diets are worked out at different levels of cost. Weekly market lists of the necessaries are set up. Indeed, so practical is this application of science to every-day life that menus and recipes, gauged to the suggested food supply and at lowest cost, are sent out from week to week, in a press release containing information as to the nutritive values of each and all of the common foods.

The home economics research program has developed in the Department of Agriculture from a beginning more than 40 years ago. Congress in 1887 created agricultural experiment stations in connection with land-grant colleges, and provided for study of the "composition and digestibility of the different kinds of food for domestic animals." In 1893 the Secretary of Agriculture recommended that "questions relating to the use of an agricultural product as food for man should also be considered." President Cleveland, in his message to Congress, commented: "When we consider that fully one half of all the money earned by the wage earners of the civ-

ilized world is expended by them for food, the importance and utility of such an investigation is apparent." Congress voted that year $10,000 "for the study of human food and human nutrition," and the important researches of Dr. W. O. Atwater, already begun elsewhere, became the basis for subsequent work of the Department of Agriculture in this field. That work was carried on from 1894 to 1914 in the Office of Experiment Stations, where the program was widened to include investigations of the relative cost as well as the composition and nutritive value of food materials; studies of dietaries, of the digestibility of certain foods and of the principles of human nutrition.

In 1915, following the passage of the Smith-Lever Extension Act, the Office of Experiment Stations was absorbed in a new unit of the Department of Agriculture called the States Relations Service, through which home economics research was continued under authority of Congress "to investigate the relative utility and economy of agricultural products for food, clothing and other uses in the home. . . ." Thus the field was extended to include the consumption value of all the agricultural products used in the material equipment of the home. Obviously important here, in addition to food products, are cotton and wool.

The Bureau of Home Economics was established in the Department of Agriculture in 1923. This action came as part of a plan by the then Secretary Henry C. Wallace to strengthen the scientific work of the department in respect to home economics. It coincided also with a general reorganization of the whole department on functional lines which separated regulatory, research, and extension work. Thus the field of home economics research was again broadened and this time dignified by the status of a bureau. In addition to studies in foods and nutrition, and the utilization of agricultural products for food, clothing and household furnishings, the bureau now studies economic problems of the home, standards and costs of living, time and energy required for household operations, and trends of household consumption of agricultural products.

Much of the bureau's work in these varied fields is carried on in cooperation with other branches of the department and with state organizations. At present, for example, vitamin studies are under way as a part of poultry-feeding experiments at the experimental farm operated by the Bureau of Animal Industry at Beltsville, Md. Vitamin D, essential to prevention of rickets in children, but not widely distributed in the common foods, is present in the yolks of eggs. Investigators had found, also, that the vitamin D content of egg yolks is greater if the hens are fed on a diet including either cod-liver oil or viosterol, or if the hens are irradiated. Tests have recently been made in the bureau's nutrition laboratory to discover which of these methods of treatment is most effective. These tests show that when cod-liver oil is fed at the usual level, its vitamin D is more efficiently stored in the egg yolk than is the vitamin D of an equivalent amount of viosterol. They show also that 2 per cent. of cod-liver oil is more effective than 1 per cent., but that no greater storage of vitamin D is effected at a 4 per cent. and 6 per cent. level. Fifteen minutes irradiation of the hen with a carbon arc lamp apparently has the same effect on vitamin D storage as 1 per cent. cod-liver oil in the diet. As to viosterol, in these experiments the anti-rachitic value of egg yolk seemed to vary almost as the concentration of viosterol in the diet of the hen.

Another vitamin study now in progress is part of a plant-breeding experiment looking to the production of a variety of potato rich in vitamin A. A yellow-fleshed South American potato,

which does contain vitamin A, is crossed with the common white potato. The breeding experiments are carried on by the Bureau of Plant Industry, and the Bureau of Home Economics makes the vitamin assays of the product. The hope is that a yellow-white potato can be obtained which will contain vitamin A.

Again, potatoes of given varieties, grown under controlled conditions, are tested to determine the effects of different production factors on the cooking quality and palatability. This work, also, is done in cooperation with the Bureau of Plant Industry. Experiments with rice have shown that different varieties require different cooking periods, and that this is true also of newly harvested rice as compared with rice that has been stored for a year or more. Therefore the bureau has suggested to the trade that rice of different varieties or of different ages be sold separately, not mixed. A special study of vegetable cookery is under way to determine methods of preparation that will maintain the vitamin and mineral content of the vegetables, as well as develop and retain the flavor.

Meat studies are in progress to determine the influence of such production factors as breed, sex, feed and age of the animal, on the edible quality of the meat, and to establish a scientific basis for meat cookery. These experiments are carried on in cooperation with the Bureau of Animal Industry and state experiment stations. A satisfactory home method of canning meats and chicken would help the farm housewife to have a better balanced food supply the year around. To develop such a method is the object of other experiments in the food utilization laboratory of the Bureau of Home Economics that tax the knowledge of food specialists, physicists and bacteriologists.

The comparative qualities of different commercial fats are being studied in a series of tests for flavor, creaming power and desirability for deep-fat frying. Included in the study are lards of different melting-points derived from experimental animals produced by the Bureau of Animal Industry. Under a similar plan of inter-bureau cooperation, the effect of a hen's diet upon the physical and chemical properties desirable in eggs for use as a leavening agent are being studied.

In the field of household textiles, the bureau is engaged in the first effort so far made to relate fiber production researches to household utilization. Cotton and wool, as the major subjects of these studies, are manufactured into fabrics under controlled conditions and subjected to wear, laundering and laboratory tests. The relative value of different varieties and grades of fiber for different types of fabrics is thus determined in terms of actual performance.

The durability of cotton materials is affected by the methods used in care and laundering. Studies are therefore being made of the reaction of different varieties and grades of cotton to the temperatures and reagents used in laundering.

Experiments to develop improved methods of finishing cotton fabrics, both in the mill and in laundering, are also carried on in the bureau's textile laboratories. The penetrating and coating power of different sizing mixtures and the effect of these properties on the appearance and usefulness of the fabric are subjects of investigation. These findings will assist the textile manufacturer as well as the housewife to select the suitable finish for a given fabric.

Another part of the textile work combines the development of new fabrics for specific consumer needs with a study of designs for household textiles and garments. New fabrics for special household uses are developed through experimental study and new designs are worked out for household articles which make an effective use of cotton and wool. The bureau was the first agency

in this country to initiate research on clothing designs for children, taking into account health and training of the child. To date, 29 of these designs have been adopted and put on the market by eight commercial pattern manufacturers. Exhibits of the garment models are in constant demand by public health clinics, medical associations, visiting nurse associations, schools, colleges and other organizations concerned with child welfare.

In addition to studies of individual agricultural products, the bureau considers the consumption habits and needs of the family for goods and services of many kinds. Different groups of the population and of families of different economic status are studied. Some are marginal groups, where the need for improvement in standards of living is especially urgent. The information obtained is used by extension workers and others in helping home-makers to make use of family resources. It contributes also to the knowledge of consumer demand which is needed for better adjustment of production to consumption.

Food consumption studies are an especially important part of these standard-of-living investigations. Dietary records are kept for definite periods at various seasons, covering quantities and costs of the different foods consumed by families, individuals, or institutional groups of various social and economic levels. This information is analyzed to determine the amounts of different types of food consumed, their adequacy from the standpoint of good nutrition, and their economy in the diet. On this basis practical suggestions are made to home-makers as to food selection and purchase. For three years past, special attention has been given to low-cost adequate diets and the problems of relief agencies.

The economic researches of the bureau also include studies of the work now carried on in the home and methods of increasing the efficiency with which it is done. The primary purpose is to aid home-makers to make the best use of their time and energy, and of the money spent for household equipment and for other methods of lightening housework. Such information is especially needed at the present time by farm women, where the necessity for a live-at-home program adds many household tasks to schedules already heavy.

The economic value of the home-maker's time when spent in the various household tasks is judged by comparing the money costs of the homemade and the commercial product. There is, of course, a very wide range in the economic return from the different tasks that can be done in the home, and information from these studies provides home-makers with a scientific basis for the choice of tasks on which to spend their time. These studies of household efficiency are also of value to those interested in the planning and building of rural and city homes, to manufacturers and distributors of household equipment, to bakers, laundry owners and others interested in the extent to which commercial substitutes are replacing home-made products and services.

The fundamental point of view from which all the work of the Bureau of Home Economics is carried on is that of the home-maker, who is usually the purchasing agent of the household. The home is the great consumer market for the chief agricultural product, which is food; for other agricultural products such as cotton and wool; for manufactured products in the form of household equipment and furnishings. Very clearly, then, a Bureau of Home Economics, in the U. S. Department of Agriculture, is a link between producers and consumers in the greatest of all markets. It is in a position to give aid, directly, toward a planned economy where consumers' needs and production programs are coordinated.

# THE BACTERIOPHAGE IN INFECTIONS OF BONES AND JOINTS

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It has been said, and with no exaggeration, that upon the activities of bacteria the very existence of man depends. Without bacteria there could be no living organism in the world. Every animal and plant owes its existence to the fertility of the soil, and this in turn depends upon the activity of microorganisms. This also can be said in reference to the digestion of man, particularly in the lower segment of the bowel. Few people assign to bacteria the important position in the world of living things that they justly occupy, whereas only a few of the bacteria known to-day have developed in such a way that they can live in the human body, and for every one of this kind there are numerous others which are perfectly harmless and in no way regarded as the enemies of man, but must be numbered among his best friends.

It has only been recently realized that of these benign varieties the bacteriophage is probably the most life-saving and influential in the welfare of mankind. It has been described by d'Hérelle as an ultra-microscopic living organism which is parasitic in the pathogenic bacteria and reproduces itself. It is so potent that the principle is often active in a dilution of one in 100 million. Most strains of bacteriophage, however, are specific for certain kinds of bacteria or even for certain strains of these species. The bacteriophage may be present in small quantities in culture but remain unnoticed and may be the cause of variations occurring apparently spontaneously. The nature of the bacteriophage has stimulated a large amount of research on account of its impending importance throughout the realm of medicine and surgery.

In the field of entomology beneficial pests or parasites have been long used with much benefit in the economic life of man in particular relation to domestic animals, crops, etc., in counteracting the activities of injurious species. The benefits derived by man from beneficial organisms are very great, and it is most fortunate that practically every destructive species is preyed upon and kept within bounds by the attacks of other organisms, either parasites or predators. But for these natural controls, man would stand little chance of successfully competing with these hosts of injurious animals. Biological or natural methods of controlling pathogenic organism in the human subject have not been considered possible until this newly observed phenomenon was first described by F. W. Twort (1915) and F. d'Hérelle (1918), who found an ultra-microscopical parasite of pathogenic bacteria which had markedly beneficial effects in certain acute intestinal diseases, such as bacillary dysentery and cholera. This parasite he called the "bacteriophage" because it lived on virulent pathogenic bacteria and destroyed them, thus in many instances saving the patient's life. There were, he demonstrated by laboratory experiment, several varieties or "races" of phage, each with a preference as to the type of bacteria it would destroy; but also having certain adaptable destructive influences toward other strains of bacteria.

In one of his earliest experiments with dysentery bacilli he added about 0.0001 cc of bacterial culture to a young broth culture and subcultured the mixture immediately to an agar slant. Ultimately, the surface of the agar was well covered with a roughened layer of the

multiplying bacteria. Then, after a long period of time, two little islands appeared, two clear plaques perfectly circular in form where the agar was bare, entirely free of all traces of the bacterial colony. D'Hérelle explained this striking phenomenon by the spontaneous appearance of a bacteriophage which absolutely destroyed the bacteria with which it came in contact.

To prove this, his next step was to apply a platinum loop to the roughened surface of the agar and transfer a bit of the bacterial colony to a test-tube of clear bouillon and incubate it. Within a short time, the tube was so teeming with bacteria that it was turbid and opaque. D'Hérelle then transferred to this turbid culture an infinitesimal portion of one of the clear plaques on the agar slant. After a few hours, the bouillon, as if by magic, became perfectly clear and transparent, and centrifuging of the culture failed to disclose any bacteria whatsoever. Not only had all bacteria been killed, but their bodies had been lysed or dissolved.

Now if a chemical germicide had been placed in this tube or heat applied, the bacteria would have been killed, but at the bottom of the tube there would have been a sediment, a deposit as a result of centrifuging, millions of dead bacterial bodies. Not so in this tube of d'Hérelle. There was not a trace of sediment. Not a dead bacterial body could be found.

The analogy between these experiments and the spontaneous appearance in a bone or joint wound of a bacteriophage, when one seals it up for a long period of time (6 or 8 weeks) with such substances as vaseline gauze, Bipp or my paraffin tampon, is striking. Following operation or at subsequent dressings, when one fills the wound with the paraffin tampon it is discharging profusely. When the dressing is removed, at the end of 6 or 8 weeks, there is a marked change. The granulations are red, velvety, and in every respect the wound has the appearance of a healthy one, provided a bacteriophage has appeared spontaneously. It should be noted that the same phenomenon, namely, the spontaneous appearance of a specific phage, has occurred here as in the test-tube observation of d'Hérelle. The important element in the two phenomena, the one in the test-tube and the other in the wound, was a sufficient lapse of time without sweeping away the discharges or products of the wound or without the introduction of extraneous contamination. According to d'Hérelle, certain races of phage were always present in the intestinal tract of man. Their parasitic activities, however, apparently increased in accordance with the number and virulence of pathogenic bacteria with which they came in contact and had a specific action. It was further found possible to increase and intensify this parasitic action by administering doses of a laboratory prepared highly specific phage.

The action here is analogous to that which happens in a citrus grove of Florida, which is infested with an organism known as the purple scale, which kills orange trees just as pathogenic bacteria kill human tissue. There are open to the agriculturists two methods of combatting this destructive organism: (1) to spray his trees with a strong chemical which is somewhat analogous to the Carrel-Dakin treatment of a wound, and the other method is to use a beneficial parasite or, speaking in surgical parlance, a bacteriophage, to destroy the resistant enemy organism. The beneficial parasite commonly used in this instance is known as the red-headed ray fungus. This organism penetrates the body of the adult scale and eventually kills it as well as its eggs or larvae. If the fungus does not spontaneously appear in the grove, which it usually does not, the agriculturist introduces it from the laboratory himself. Relatively small inoculations will suffice in that it proliferates rapidly and spreads throughout the grove. It is a biological agent

and is actively aggressive in its destructive influence upon the enemies of the grove. On the other hand, the chemical spray will have no influence except upon the organisms that it mechanically reaches, or a rain may immediately wash it away, and in this particular scale its potency is very unsatisfactory. Further, it has been found undesirable to spray with chemical a grove in which the beneficial parasite has been introduced or has appeared spontaneously, as the chemical has been found to be more destructive to the beneficial parasite (or bacteriophage) than to the pathogenic organism. A lesson, I believe, should be drawn from this with respect to the surgical use of the bacteriophage in wounds. When one is looking for the beneficial action of the bacteriophage he should never introduce into the wound a bacteriocide in the form of a chemical.

Since time immemorial infected wounds have been the surgeon's *bête noire*. One needs only to read Homer and other ancient writers to realize this, and a review of wound treatment throughout the ages gives renewed evidence of the old adage that doctors differ, and proves again that scientific advances move in cycles. The search for ideal wound treatment is centuries old. Primitive man's wounds were dressed with dry moss or fresh leaves, ashes or natural balsams. The spear and arrow wounds of Homer's heroes were treated by sucking and cauterization with hot irons and filled with pounded root powders. After any of these local measures had been carefully applied, appropriate incantations, recited with religious fervor, were considered necessary to insure healing.

Enough has been stated to show the unusual attitudes taken in reference to wounds throughout the ages, and there has been no more revolutionary departure in this important part of surgical practise than the one I am to set forth in this communication.

The first intimation of abandoning the customary frequent dressing of wounds was a brief description by Gooch of his doctrine of non-interference. If his technique were described in more detail we might find a resemblance to the Bipp or Orr treatments. Hunter, in connection with his classic study of circulation and information, remarked that it was sometimes just as well to let a wound alone. The nineteenth century was outstanding because of the introduction of antiseptics and germicides by Lister.

With the world war came the Carrel-Dakin treatment, the acme of antisepsis. It combined qualities which no previous wound antiseptic had. It did not harm the tissues. It dissolved the wound exudates and thereby permitted the nascent chlorine which it contained to penetrate to the bacteria in the deep recesses of the wound. As compared with previous methods of treatment the results were excellent. There were, however, obvious objections to the treatment, and as the rush of war surgery abated the objections gained more weight. The frequency of irrigation and dressings were distressing to the patient, arduous for the surgeon, and always associated with the risk of reinfection with extraneous organisms. It also necessitated prolonged hospitalization, a serious drawback of any treatment, particularly in these days of depression. The necessity of cutting a window for the insertion of the tubes and the softening of the cast by the constant introduction of the Dakin fluid rendered immobilization imperfect, which is so important in the prevention of oedema in the granulations, deep portions of the wound and the surrounding soft structures. A uniform pressure over the wound, as well as the neighboring structures, is most important. The above enumerated handicaps also applies to the use of the maggots.

My present method of treating osteomyelitis and suppurated joints, both

acute and chronic, is as follows. For purposes of brevity, the surgical technique will not be discussed at this junction. Suffice to say that the indications are the same and the precise operative surgical work is carried out whether the phage is used or not.

*Technique:* The usual sequestrectomy and saucerization are completed, and a culture is taken. I do not use alcohol or iodin, lest they interfere either with the development of the spontaneous phage or with the specific laboratory-bred phage after its introduction. (If a specific phage has already been found from a culture previously taken from an existing sinus, two thirds of a test-tube of this phage is poured into and over the wound, so that the whole surface is bathed.) The wound is then filled with a paraffin and vaselin mixture, 75 per cent. paraffin to 25 per cent. vaselin, providing the wound is shallow and there is no danger of its orifice at the skin closing too soon; or, in cases where the wound is deep and made through heavy muscles, 90 per cent. paraffin to 10 per cent. vaselin is employed. No vaselin gauze whatsoever is used. The paraffin and vaselin are heated to 110° F. and poured in as a liquid or forced in by pressure through a large syringe. In most cases, the syringe is the method of choice, in order to insure penetration of the mixture to the innermost recesses of the wound. The orifice of the wound is closed over with several layers of gauze saturated with the same paraffin compound and the end of the syringe is inserted through a tiny hole in this saturated gauze and the wound cavity, with all its recesses, completely filled.

A rubber catheter is inserted through the paraffin-vaselin wound tampon to the bottom of the bone cavity. The other is allowed to project through the dressings and cast (which are applied as usual), with a sterile gauze or cotton over the end. If the laboratory examination of the culture reveals that it is possible to develop a bacteriophage specific for the organism presented, ten cubic centimeters of this phage are injected through the rubber catheter once or twice a week. Care should be taken when making periodic injections not to infect or contaminate the end of the tube. Should the bacteriophage appear spontaneously in the wound, injection of the laboratory-bred phage is still of advantage in that it accentuates the action of the native phage and may be a more specific one. This practise is of still further advantage because if an original phage does not completely destroy a culture, the organisms that survive give rise to a resistant strain which may not only be pathogenic for its host but later be unaffected by a more specific bacteriophage. In large wounds, several catheters may be inserted, some of which are multifenestrated. Inasmuch as the catheter is firmly imbedded in the paraffin-vaselin tampon, the injected phage fluid can not flow backward between the catheter and the tampon. It must, therefore, make its way *inward* between the tampon and the wound granulations, and thus, by reason of its own bulk, spread widely. Furthermore, since the phage is, by nature, a multiplying organism, it will thus automatically spread over the wound surface.

At the end of eight weeks the cast is removed and the wound dressed, great care being taken not to traumatize the granulating surfaces. The discharge around the edges of the wound is wiped off very gently with sterile gauze and the skin cleansed with benzine.

If the wound is not entirely healed when the cast is removed, it is again bathed with a test-tube of the prepared specific phage fluid and a catheter or catheters inserted to the depths of the wound. A paraffin-vaselin tampon is used as before and a cast applied for an eight-week period. A culture is also taken at this time to determine whether the bacterial flora of the wound has

changed, and also whether a more specific race of phage can be obtained. Periodic injections through the catheter are given as before.

I have recently completed a statistical study of 100 consecutive cases treated by this method which shows that the average healing time for a case of osteomyelitis so treated is about six months. The type of infecting organism varies—staphylococcus, or a mixed infection with staphylococcus predominating, being the most frequent. It is interesting to note that the bacillus Welchii appeared in seven of the series of 100 cases. However, the rod was extremely weak and attenuated and did not interfere in any way with the healing of the wound. The flora changed in 22 per cent. of the cases, usually to a more favorable type of organism, resulting in rapid healing.

Those cases in which a native phage develops usually do very well without the insertion of a laboratory-bred phage. However, in view of our latest investigations, we feel it is wise to inject periodically a race of phage of the highest potency, in order to have at work for a maximum period of time a phage of the highest specificity. In this way, any possible decrease in potency of the native phage is offset.

The treatment of a group of cases of osteomyelitis with complications, such as infected fractures and joints, entails a multitude of considerations. In most of these cases, we have deep wounds extending into the bone, with varying degrees of infection. The ideal wound dressing must, therefore, have a degree of solidity sufficient to restrict the tendency of the orifice at the dermis to close earlier than the depths of the wound. At the same time, this tampon should be such that it can be inserted in practically a fluid state, in order to flow uninterruptedly to every recess of the wound; it should then become semi-solid, thus tending to conserve the original contour of the wound, avoid adherence to the bone, and, bit by bit, extrude automatically as granulations fill up the depths of the wound, or as the contractions of healing and cicatrization demand. The paraffin tampon measures up to these requirements very well.

I do not favor the vaselin, vaselin-gauze dressing for several reasons:

(*a*) It is impossible to satisfactorily control the consistency of the vaselin, vaselin-gauze tampon. Due to the ingredients comprising it, this tampon can not, at best, be uniform in its consistency or tend to hold its original conformation.

(*b*) Later experience has shown that, even when an excess of vaselin is added with the vaselin gauze, the gauze is still apt to become adherent to the bone at the bottom of the wound and so resist extrusion of the tampon and delay healing.

(*c*) The wound granulations are likely to strangulate through the meshes of the gauze.

None of these complications ever arises with the paraffin and vaselin dressing, which, because of its proper degree of solidity for the particular case, the uniformity of its consistency and its slippery surface, will always extrude much more satisfactorily than the vaselin, vaselin-gauze dressing. Furthermore, it has been found that the bacteriophage occurs spontaneously just as frequently as with the vaselin-gauze dressing; also, the laboratory-bred phage, when introduced, acts as favorably. I have been unable to find any shortcomings of this dressing as compared with either the Bipp or the vaselin, vaselin-gauze dressing. Bipp, however, may be contra-indicated because of the possible unfavorable chemical action of the iodoform upon the bacteriophage.

In addition to its application to infected bone wounds, the bacteriophage has proved a most efficacious specific agent in combating lesions such as fu-

runcles, boils, carbuncles and phlegmons. For these conditions it may be applied in two ways:

(1) It may be thoroughly rubbed over the surface of the wound and the lesion covered by sterile pads soaked in bacteriophage; or, if the lesion is of extensive size or depth, it may be dressed with the paraffin and vaselin tampon with a catheter incorporated for periodic introduction of bacteriophage.

(2) It may be injected subcutaneously into the soft parts by means of a hypodermic needle about the periphery of the lesion.

In *bacteriemia*, particularly with staphylococcus aureus, a bacteriophage, prepared with asparagin as a medium and injected into the blood stream, has, in the hands of Dr. MacNeal,[1] reduced the mortality from practically 100 per cent. to less than 50 per cent., even when there have been two positive blood cultures. Not only is the bacteriophage a successful local therapeutic agent, but it has the added advantage of helping to establish a possible general so-called immunity on the part of the patient. Also the bacteriophage is, to some degree, effective in experimental animals when injected at a site distant from the infected focus.

The invariable excellence of the results of this new method of treatment for infected wounds should make it unquestionably preferred by all those who experience its advantages over former methods. I believe that the bacteriophage will eventually become one of the surgeon's important weapons against infection. Its potency has become so widely recognized that certain governments (India and Brazil) have passed laws that it be kept constantly on hand for use in certain intestinal diseases. My desire is to stimulate the interest of the surgical world in a phase of bacteriology which will have a profound influence on the future treatment of surgical infections.

My experience with this new method for treating osteomyelitis has convinced me that it is far superior to any other method I have used, and this conviction is borne out by the statistical study which shows the time of healing materially reduced. A summary of the advantages of the dressing follows:

(1) It is simple in its application, requiring a minimum amount of labor on the part of the surgeon and his staff.

(2) It does not interfere with the immobilization of the part (as, for example, in the case of a compound infected fracture or suppurating joint), nor does it favor oedema of the granulations or the soft structures because of inequality of pressure at or in the immediate neighborhood of the wound, since there is no window in the cast. This is quite contrary to the Carrel-Dakin or maggot method of treatment, both of which must, of necessity, have a window in the cast. I believe that a uniform pressure over the wound and neighboring tissues (such as this method affords) will avoid oedema—an important consideration in the healing of a wound, as is exemplified in the case of varicose ulcers.

(3) The paraffin-vaselin tampon automatically yields to the encroachment of granulation, healing and closure of the wound, thus gradually extruding and keeping up a constant physiological pressure upon the surface of the wound at all times. This is more effective than frequent dressings by the surgeon, and, in addition, avoids the possibility of reinfecting the wound by a foreign flora of bacteria.

(4) This dressing is favorable to the appearance of a native bacteriophage and to the periodic introduction of a laboratory-bred phage.

(5) It requires a very short period of hospitalization, which at this time of depression is one of its most important advantages.

[1] New York Post-Graduate Hospital.

# SCIENCE SERVICE RADIO TALKS

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## CHEMISTRY AND DAILY LIFE

By Dr. CHARLES M. A. STINE
VICE-PRESIDENT, E. I. DU PONT DE NEMOURS AND COMPANY

ONLY a few generations ago, manufacturing consisted almost wholly of changing the form of raw materials found in nature. In some measure, this is the case to-day and is likely to continue indefinitely. For instance, trees are felled and sawed into lumber of various shapes. In turn, the lumber is worked by machinery or by hand in the making of, say, furniture. Again, the fleecy content of the cotton boll is spun into yarn and the yarn woven into fabric. True, the surface of fabricated wood may be modified in appearance or disguised by the application of lacquer, varnish, paint or some other finish, while cotton yarn may be bleached or dyed, or the cotton textile may be bleached, dyed or printed. However, a wooden article, produced by merely changing the form of the raw material, is still wood, while raw cotton, though changed as to its form, remains cotton.

Facilities for making things of wood, cotton and other natural materials long ago passed through a transition from the use of hand tools—the spinning-wheel, hand looms and other manually-operated equipment—to power-operated machinery and looms and the like. Thus it was that we entered the Machine Age. But manufacturing was almost wholly concerned with altering only the shape of natural materials.

During the past quarter of a century, and more particularly during the less than two decades since fateful 1914, with the start of the world war, there has grown up in the United States a tremendously important new industry, described broadly as the diversified industrial chemical industry. Therefore, some who like to coin new words and phrases are wont to style the time in which we now are living the Chemical Age.

In these modern days, the industrial chemist, along with the designers of wood-working machinery and textile machinery, is interested in wood and cotton, but the chemist's interest in such basic raw materials is for an entirely different reason. The chemist is not concerned at all about simply changing the forms of wood and cotton. What he sees in these two materials are sources of cellulose. He takes wood, if it be of the kind rich in cellulose content, and makes from it rayon and certain other products of a considerable group. Of cotton, the industrial chemist makes a very much wider and more diversified range of products, largely because cotton is almost pure cellulose. In either the case of wood or of cotton, the finished products are in no respect similar to the raw material in appearance or physical or other properties.

Although cotton in the form of fabric is not the form most widely used by the industrial chemist, it is entirely possible to take a cotton dress or a cotton shirt and by chemical processes make rayon, motion-picture film, a lacquer for automobile finish, transparent waterproof cement, or any one of many others of the chemical products used daily in the home or elsewhere.

Before the present developments along the lines of industrial chemistry, manufacturing was limited to the use of natural materials. Also, man had to take these substances as nature had produced them for purposes of her own economy. As a result, many of these natural mate-

rials possessed serious undesirable properties, judged from the standpoint of their applicability to industrial and other uses.

Take rubber as an example. Natural rubber, as is well known, is derived from latex, the milky juice of the rubber tree. It is believed that the purpose latex serves is to protect the tree from certain insects. This being the case, with nature not having developed this juice for man's use for such purposes as the making of overshoes, automobile tires and various other rubber products, it is not at all surprising that latex has certain undesirable properties.

An animal's hide or the skin of a reptile is provided by nature with a view not only to meeting the general requirements of species but to suit the peculiar needs of the individual. The texture and the physical properties of any hide or skin may be further modified by the health of the creature, the season of the year and other factors. These considerations make it obvious that there is a marked difference in uniformity; in fact, no two pieces of such natural materials are exactly alike. It is, therefore, very evident that nature is not at all concerned about the use of the external coverings of her creations in the making of handbags, bookbindings, furniture coverings or for any of the other artificial uses to which skins and hides are put.

Similar considerations apply equally to such natural products as ivory, mother-of-pearl, and to the gums and oils used in paints, enamels and other finishes, to mention but a few. Besides, with many materials found in nature, there is the limit of size to further handicap those who would make use of the stuffs. Nor are some of these materials always to be found close at hand; rather it is necessary frequently to go literally to the ends of the earth for certain raw materials, while all too often the available supply is very inadequate.

Again, the multitudinous and special requirements of our complex present-day life make necessary things which were not even dreamed of in the so-called good old days of the horse and buggy, the windjammer and tallow dips. And it is to the chemist's test-tube that we moderns look for new materials and new applications to increase our comfort and enjoyment, our advancement along economic and social lines and even certain phases of political progress.

Since rubber is at once one of the most familiar and most useful of materials, let us consider what the chemist has achieved in making it synthetically. Known as DuPrene, synthetic rubber is now produced from such common materials as coal, limestone, salt and water. These are found right here in our own country, and in the greatest abundance. Therefore, it is no longer necessary to depend upon distant sources of supply of natural rubber, should a situation arise that would make it either necessary or desirable to manufacture rubber to supply all our needs in a factory instead of importing the natural product from distant parts. Not only is DuPrene a satisfactory substitute for natural rubber for almost every purpose, but it is, in fact, superior to natural rubber for certain uses.

Cowhide and snake skins can be so closely simulated in appearance by lacquered fabrics that it is not necessary to depend entirely upon the natural products for materials for use for bookbindings, upholstery, hand luggage and various other purposes. A woven cotton backing with a surface coating of lacquer, derived from nitrating the linters shaved from cottonseed, gives us a waterproof material of fully sufficient strength and great durability. It can be made in any desired width and length, while every square foot can be identical in appearance and quality, owing to chemical control in the manufacturing of this lacquered fabric.

From cotton as a basic raw material, the industrial chemist makes plastics

with the appearance of ivory or mother-of-pearl, and in artistic or other effects of which there are not to be found counterparts in natural substances.

Synthetic gums and oils developed in the research laboratory are now produced in the chemical manufactory for use in the making of interior and exterior finishes of a distinctly different type from enamels made with natural gums or paints using natural oils in their composition. Camphor, which, as a natural product of a tree, comes from Japan and other parts of the Far East, may now be made by chemical processes from one of the constituents of turpentine, while the turpentine is obtained from the pine stumps of our own southern states. Though the extent of the use of camphor in the manufacture of chemical products may be little appreciated, it really amounts to thousands of tons annually.

What are known commercially as naval stores consist of materials from pine stumps and include rosin, turpentine, pine tar and pitch and pine oil. The industrial chemist uses rosin in making sealing wax, electrical insulation, paper, paint, varnish, soap, linoleum, printing ink and for foundry purposes. Turpentine is used by the chemist in medicines, perfumes, paint, varnish, shoe polish and, as has been mentioned, synthetic camphor. Pine tar and pitch find uses as rubber softeners, in paint and on rope or cordage. Pine oil is used by the chemist in disinfectants, for reclaiming rubber, in medicines and perfumes, for mineral separation and in the textile industry. Without the aid of chemistry, the southern pine stump would remain little more than an obstruction on cleared land. Chemistry gives the pine stump an industrial value.

Fixed nitrogen for industrial and agricultural purposes is highly important. Not so very long ago, the chemical manufacturer and the farmer had to depend very largely on natural nitrate of soda imported from distant Chile, though some was obtained by the distillation of coal. Quite a different picture is now presented, with chemistry obtaining a plentiful supply by fixed nitrogen from the air as ammonia.

The scientific research worker and the industrial chemist are giving lively and increasing attention to the American farm as the source of substitutes for a considerable number of basic materials. It is now realized that the millions of tons of agricultural wastes which are produced annually in this country offer a potential source of basic substances for use in industry. Eventually this must increase demand to such an extent that the chemical and other manufactory will consume more of the products of agriculture than does the human stomach. This holds the prospect of greater prosperity for the tiller of the soil.

The importance of the midwestern section of our country from an agricultural standpoint could well operate to make it at some future time a vast industrial locality, because of the availability of farm products for which the scientist will discover manufacturing uses. Such a development finds a striking parallel in the South, which from an almost wholly agricultural territory has also become a highly important industrial one by reason of the fact that the South's cotton crop and certain of her natural resources have supplied materials needed by chemistry for the creation of entirely new industries and the revolutionary development of some old lines of manufacturing.

Throughout the entire country new industries have come into being as a direct result of fundamental chemical research, and the utilization of the results in chemical manufacture. New needs of humanity have, time and again, been supplied by materials developed in the laboratory. The fruits of fundamental research along chemical lines in many cases represent indispensable knowledge of various materials which occur in nature. Continual additions to

this field of knowledge are indispensable to the development of new products and appliances for increasing man's comfort and improving his health and living conditions.

Opportunities for employment also have been vastly expanded as a result of jobs created by new industries established to manufacture products developed by the chemist and his coworkers. As a result of the discoveries and inventions of our scientists, America has come to a state of economic independence which is practically complete along every line. We have fixed nitrogen and we need no longer import nitrates from Chile; we seem to be about to develop our own potash resources in the Southwest; we are able to make, should the occasion arise, synthetic rubber of acceptable quality. These are merely a few striking examples of the tremendously important contributions which our own development of chemical manufacture has made toward American economic independence.

# EXPLORING THE ATLANTIC'S GREATEST DEEP

By Dr. PAUL BARTSCH

CURATOR OF MOLLUSKS AND CENOZOIC INVERTEBRATES, U. S. NATIONAL MUSEUM; DIRECTOR, JOHNSON-SMITHSONIAN DEEP-SEA EXPEDITION

The Johnson-Smithsonian Deep-Sea Expedition to the greatest of the Atlantic's deeps, the Puerto Rican Deep, was made possible through the generosity of Mr. Eldridge R. Johnson, of Philadelphia, the genius who organized the Victor Talking Machine Corporation. Mr. Johnson placed his wonderful yacht, *The Caroline,* at the disposition of the Smithsonian Institution and equipped her without quibble or stint with the most up-to-date instruments for marine exploration. Through the cooperation of all agencies at home and many abroad, we supplied the ship with all the necessary gear to enable us to achieve what I may now claim, without egotism, to be a greater return than that obtained by any previous expedition in an equivalent period of time. This material is now in the hands of specialists for report. You will also be pleased to hear that we are busily at work with the creation of a new winch that will enable us to obtain specimens from any depth, next year, when we return for a final effort to the Puerto Rican Deep.

To-day I thought you might like to hear something of our biological catches. As all living creatures of complex organization begin as a single cell, I may be pardoned by beginning with the unicellular creatures, secured with our Nansen water bottle and our finer tow nets and bottom samples. Most of these —whether plants, such as diatoms and algae, Foraminifera (the chalk animalculae) or Radiolaria (dwellers in glass houses)—are so exquisitely sculptured and ornamented that the term "beautiful" appears hackneyed and trite when applied to them. These minute plants and animals occur in such vast numbers, sometimes several millions in a single quart of water, that we should really look upon the sea not merely as a watery waste, but as a richly stocked aquarium.

This teeming minute life is particularly abundant in the upper stratum of the sea, where the penetration of sunlight makes possible the photosynthetic action of the chlorophyl organs of the tiny plants. We may therefore agree with the author who first called the upper hundred fathoms of the sea "the grazing ground of the oceans." It is this rapidly multiplying microscopic life that furnishes the food supply to the larger small creatures, which in turn feed larger forms, even the huge whales,

and, finally, the king of all animals, man. Nor do they serve as food alone, for the Foraminifera, when they shuffle off this mortal coil, sink slowly to the ocean floor, where they form an ooze which in time may consolidate into rock, as evidenced by the chalk cliffs of England that caused Caesar when he first saw them to give the name Albion to the land.

So the geologist, seeking the earth crust's treasures, drills into the ground, and an examination of the core which he brings up, for Foraminifera and mollusk shells, will help him know the stratum to which his drill has penetrated; they are his finding and directing marks. The Radiolaria, on the other hand, gives us Barbados earth, and Tripoli your polishing pastes and powders.

The next higher group, the sponges, were well represented in our catch, ranging from the toilet sponge group to the beautiful glass sponges, of which we obtained three species. When it comes to the Coelenterates, I might devote an hour to the discussion of the coral reef without wearying you, I am sure. Of flat and round worms Dr. Price obtained no end of new species and higher groups parasitic upon deep-sea fishes, which had never been explored for such companions. The Bryozoa and Brachiopods yielded their share.

The Echinoderms furnished many curious serpent or brittle stars, sometimes more than a gallon full in a single haul; also sea stars, sea eggs, curious brilliantly colored Holothurians, and sea lilies, both sessile and stalked. The latter furnished a new experience for me and rendered me almost as excited as the novices on the cruise. Of the stalked sea lilies we secured no less than two dozen in a single haul.

Worms were caught a-plenty, and Crustaceans were abundantly represented in our catch. Were I to stop and discuss my pets, the mollusks, I would need at least a day to give you an adequate account of what we obtained. Suffice it here to say that we added many new species and quite a number of new genera.

Experiments have shown that highly sensitized photographic plates, exposed below 10,000 meters even for a protracted period, show no effect, and these observations have caused the general belief that animals living below this depth exist in everlasting darkness. I am not altogether convinced about this. Most of the deep-sea fishes have splendidly developed eyes—usually larger than those of species living in shallower water. Of what use would these be if Stygian darkness prevailed? Most marine creatures are phosphorescent and many of them, if not all, are more or less fluorescent; that is, they are made to glow when actuated by ultra-violet rays.

Many of the deep-sea fish are provided with highly developed phosphorescent organs and baits that they may make glow. Or some, like the hatchet fishes, when seen alive appear as if the dark parts were cut out of jet and the light areas covered with translucent celluloid and the interior provided with a toy lamp. Where you have enormous numbers of the tiny unicellular organisms, like the Peridinia, present, as I once observed in Manila Bay, they emit enough light when agitated by a passing launch to enable the occupants thereof to read a paper by their glow.

All these things make me wonder if after all there may not be a glow, like that in our atmosphere on brilliant starlit nights, present in the deeps with an occasional meteoric flash produced by the glowing bait or phosphorescent organs of some larger denizens of the deep. It also seems quite possible to me that some of these flashes may awaken and set aglow fluorescently the lesser folk when thus eradiated. A reaction of this kind offers an explanation for the marvelous development of the light-emitting organs covering the belly of the lantern fishes or the sides of many others. In my mind's eye I see the deep rendered faintly aglow

by its myriads of tiny folks, and in the glow I see momentary searchlight flashes produced by larger creatures which not only set into relief the other things but cause them to flash with a sympathetic fluorescent glow.

Probably you would like to visualize some of these denizens of the deep. Were television as widely used as the radio is to-day I should take delight in projecting pictures of some of the creatures obtained. As it is, I shall attempt to briefly describe two or three of the deep-sea fishes we caught:

### The Viper Fish, Idiacanthus

Conceive a slender, very long, eel-like purplish black body tapering from the neck to the tip of the tail, which equals about one fourth the diameter of the neck, made up of 90 miomeres or segments which are laterally compressed. The 4th to 12th of these segments bear a phosphorescent organ on their dorsal half, while the 3d to 28th have in addition two of these glowing structures on the ventral half, and on the 29th to 90th a single lamp is present. This count is repeated on the other side. We have thus no less than 248 tiny lamps on the body of this creature. Nor is that all, for there are two glowing spots on each cheek behind the eye. There are also 6 such organs on the throat, raising the total to 256, and then, most marvelous of all, there is a long filament—a chin whisker springing from the under side of the front end of the throat—which bears a bifurcated glowing torch-like tip, twenty-five or more times the size of the other structures, that can be waved in front of the fish's mouth to invite prey to come within the most exquisitely fang-toothed jaws that you can imagine.

### The Lantern Fish, Neoscopelus

Shaped like a trout, brownish red above the darker mottlings, greenish spotted about the head, provided with 118 large phosphorescent organs on the belly and a huge one under the chin. The position of these lamps on the under side of the fish certainly suggests lighting things up below as he swims about.

### The Eater of Stars, Astronesthes

Cod-shaped, pitch brown and black with a row of 46 phosphorescent organs stretching along its side a little above the ventral margin and another of 72 a little below this, that is, 118 on each side, or a total of 236 lamps. This fish, too, has a long chin whisker with a lovely glowing bulb at its tip, which it is able to swing and wave in front of its very large fiercely toothed mouth.

# NERVE MESSAGES

By Dr. D. W. BRONK
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If, while walking barefooted, you suddenly step on a sharp object your foot is quickly withdrawn. That simple act depends upon a remarkable communicating system which keeps the various parts of your body working together as a smoothly running machine. Some such system is necessary, for we are built of countless cells or units which must be regulated and controlled if they are to function as coordinated members of the living organism. This control is carried out primarily by the nervous system. The brain and spinal cord dominate and dictate the activities of the other parts of the body, and they do this by means of messages traveling over the nerves that connect them with these other parts.

In order that a business executive may efficiently govern the activities of a large number of individual employees it is necessary that he know business conditions in the community in which his

company operates, and that he also be kept informed as to the state of the various departments of his own organization. And so it is in the case of the complex living organism. There are on the surface observation outposts, or sense organs, such as the eye for light, the ear for sound, and others for touch, temperature or pain, which keep the controlling and coordinating center, which is the brain, informed about our surroundings. Similarly, there are in the muscles sensory structures which are stimulated by a contraction of the muscle, and others in the walls of arteries which respond to a change in blood pressure. From these various sense organs there go slender strands of living matter known as nerve fibers; hundreds or thousands of these fibers being bound together into nerve trunks. Over these nerves travel the messages which inform the brain about our physical environment or about the conditions within our own body. The first question I wish to consider is the nature of these sensory nerve messages.

We have long known that the main function of a nerve is to conduct very brief pulses or waves of electrical and chemical change at speeds which range from one to several hundred feet a second. If, therefore, we connect a nerve to an electrical recorder we should be able, by making use of these electrical changes that constitute or at least accompany the nerve impulses, to photograph or hear the messages which come over the nerve. In doing this it would be desirable to record what passes over just one nerve fiber, in order that the message be not confused by simultaneous messages of a very different sort traveling over hundreds of other fibers in the nerve trunk. If, for example, you connected a telephone receiver to the whole of a telephone trunk cable carrying messages from thousands of different subscribers, you would gain little information from the jumbled babble of voices in your receiver. You require one circuit at a time. Likewise, most of our knowledge regarding the text of nerve messages has come from a study of what is transmitted over the individual fibers. This was first made possible by Professor Adrian, of Cambridge University, and his colleagues, who succeeded in cutting all but one or two of the many microscopic fibers in the nerve between their source in the sense organ and the place where they are connected by means of wires to the electrical recorder. Here a serious obstacle is encountered, because the electrical pulses are so small and of such a short duration that one would expect great difficulty in detecting them. Fortunately, however, it has been possible to overcome this difficulty because the progress of radio-telephony has required the development of vacuum tube amplifiers, or "electrical levers," capable of magnifying very small electrical voltages. The instruments perfected by the radio engineer to make possible the type of communication I am using this afternoon have been employed to amplify the nerve impulses more than a hundred thousand times. And so it has been a fairly simple matter to change these electrical pulses in the nerve into the movement of a beam of light recording on a photographic film or into sound issuing from a loud speaker.

It thus became possible to find out what passes up sensory nerves to the brain when sense organs on the surface of the body are stimulated. A small piece of skin, for example, is removed from an animal, together with an attached cutaneous nerve. Wires lead from the nerve to a vacuum tube amplifier, from that to an electrical recorder, and finally each amplified nerve impulse produces a flick of light which leaves its record on a moving photographic film. When we press upon the skin we find that the sense organs for pressure send over the nerve a series of impulses regularly spaced and of a definite frequency. This is the fundamental nature of the sensory nerve message.

The impulses from any one sense organ are all of much the same size and general character. And yet we know that somehow there must be differences in the message under different conditions because it is possible to distinguish differences in the intensity of the stimulus. How the information regarding the strength of the stimulus is transmitted over the nerve fibers may be shown by increasing the pressure on the skin with which we are experimenting. We then find that the impulses follow one another more frequently. The more intense the pressure on the skin, the light in the eye or the intensity of the painful stimulus, the higher is the frequency of the impulses transmitted over the nerve fibers, the range being from about ten to several hundred a second. That is one of the ways the brain is kept informed of what is going on without and within the body.

Every sense cell requires a certain intensity of stimulus in order that it may come into action. If we shine a weak light into the eye, only those receptors which are most easily stimulated will discharge impulses. If the light be made brighter, more of the cells will respond and consequently more nerve fibers will be conducting messages to the brain. And so, as the intensity of the stimulus increases there is an increase in the number of impulses going to the brain each second, both as a result of more frequent impulses in the individual fibers and a greater number of fibers conducting impulses.

The general character of these messages from various types of sense organs is essentially the same. But then you may well ask how are we conscious of different types of sensation if the messages from the pain or pressure receptors in the skin, the light receptors in the eye and the pressure receptors in the arteries are all so similar. There is still a great deal of uncertainty about this, but the different qualities of sensation and the different reflex effects resulting from different types of stimulation are probably largely determined by where in the brain the nerve fibers end, or to what part they deliver their impulses. There is likewise very little known about how these waves of electrical and chemical change ultimately produce the complicated experience of consciousness. These are questions for another day.

One very important result of many sensory messages is muscular movement, and of its nervous regulation we can speak with some certainty. If we pinch an animal's foot, or thrust a pin into it, the foot is withdrawn. The stronger the stimulus, the more vigorously will the muscles contract. How is this activity controlled? From what I have already said you know that the stimulus has caused a series of impulses to be sent to the brain over the sensory nerves—the stronger the stimulus the greater the number of impulses. In some manner they act upon the brain or spinal cord, which in turn modifies the degree of contraction of the leg muscles. This regulation of the contraction and that involved in the voluntary control of our own muscles must be carried out by means of nervous messages traveling over the nerves that go to the muscles, for if these nerves are destroyed or injured, such a contraction is no longer possible.

In order, therefore, to find out how the nerve cells in the brain and spinal cord regulate the contraction of the muscles these messages have been intercepted and recorded. We find them to be essentially the same as those in sensory nerves and to consist of a series of impulses which cause a contraction of that part of the muscle receiving the impulses. The muscle as a whole is built up of a very large number of microscopic cellular units or muscle fibers. Each of the many nerve fibers going to a muscle transmits impulses to a certain part of the total number of muscle fibers. If more nerve cells in the central nervous system send out impulses over their

nerve fibers, the additional muscle fibers receiving these impulses will contract, and consequently the tension developed by the muscle will increase. The increased force of the contraction is due, therefore, in part to an increased number of nerve muscle units coming into action.

There is another mechanism. A weak contraction is maintained by a series of nerve impulses coming to the fibers of the muscle at the low frequency of about five to twenty a second. Each time an impulse reaches a muscle fiber that fiber will contract, and after about one one-hundredth of a second again relax. During a weak contraction, therefore, the individual fibers twitch at a rate of five to twenty times a second. The whole muscle, however, does not show such a jerky contraction but functions smoothly. This integration of the twitches of the individual fibers into a smooth contraction is due to the fact that the impulses in the various nerve fibers do not all arrive simultaneously: some fibers are contrasting while others are relaxing. As the strength of the contraction increases we observe that it is due to an increased frequency of impulses coming to the muscle, the rate increasing to over one hundred a second in powerful contractions. Now it is easily shown that the tension developed by a muscle increases as one increases the rate of stimulation. At low frequencies the fibers are able to relax between successive contractions, but as the muscle is forced to contract more frequently there is less time for relaxation between successive twitches. The result is that the fibers remain contracted a larger part of the time and so the tension maintained by the muscle as a whole increases. In this way the variation and frequency of nerve impulses going to the muscle provides an additional and effective means for delicately regulating the degree of muscular contraction.

Such are the general characteristics of the nerve messages which give rise to sensation or which control the muscular activity of the body. They are a succession of impulses that are all of exactly the same size and vary only in the rate at which they follow one another. Information regarding a weak stimulus is transmitted to the brain over relatively few nerve fibers and the impulses in the individual fibers succeed one another at fairly infrequent intervals. Strong stimuli, on the other hand, bring into action more sense organs and each one discharges impulses more frequently. Thus, the intensity of sensation seems to depend on the number of impulses reaching the brain in any given interval of time. Similar messages dispatched from the brain to the muscles govern the movements of our body. To develop a powerful contraction, nerve impulses at a high frequency are sent out over many fiber pathways. To relax the muscles, fewer fibers are used and the impulses in each fiber are sent less frequently.

These are the fairly simple messages by which an intricate organism regulates its complex activities.

# THE MAINTENANCE OF OUR MENTAL ABILITIES

By Dr. W. R. MILES

PROFESSOR OF PSYCHOLOGY, INSTITUTE OF HUMAN RELATIONS, YALE UNIVERSITY

THINK of yourself as you are to-day; then think of yourself as you were a year ago to-day. What skills, what knowledge, what interests, what basis for making better judgments, for getting enjoyment and giving it have you fully maintained or improved? Compare yourself with five years ago. Is the picture changed? Do you see improvement? If a hundred of such years were

placed end to end would it make a century of progress? Or a new low? Do you know whether the gains and the losses that you have made personally during the past year are due largely to inevitable physiological changes or to your own mental efforts and attitudes? Do you know what is to be expected, and what is to be hoped for in the way of maintenance and ability change at your age and with the capacity which you were given to start with?

The results of recent psychological investigations on adults give information about what changes people may be expected to undergo and how their abilities and interests actually test out from decade to decade. In infancy and childhood growth and development are nearly universal characteristics and the rate of improvement in sensory capacity, skill, understanding and judgment is tremendous from year to year. A motion picture showing in a single reel the development from birth to young adulthood displays such quick and important changes that we are surprised and filled with wonder. But what would a motion picture reveal that shows in yearly samples our characteristic activity from age 20 onward?

People have been talking about adult decline and the effects of age since the beginning of man's interest in himself. Just recently the conclusions arrived at by general observation have been checked by experiment; some of the myths and errors have been discovered and some of the truths defined and confirmed. At Stanford University and at Yale, extended experiments in this field have been carried on under my direction. We have studied more than 2000 adults between the ages of 20 and 95, with more and sometimes many more than a hundred representatives in every age decade below 80. It is chiefly from these studies that I am reporting results to you, because in these two laboratories the largest human population has been examined with the most varied program.

Other investigators have made very important studies of different phases of the age problem. Professor Thorndike at Columbia University has studied learning in adults, Professors Jones and Conrad at the University of California at Berkeley have studied the intellectual powers, and there are other notable contributions which you will find mentioned in a survey of this whole field of study which I reported in the *Psychological Review* for March, 1933, in an article called "Age and Human Ability."

From the Yale and Stanford studies, in which data on actual people in their actual doings can be compared from decade to decade, three impressive trends stand out for the period of maturity and beyond.

(1) Gradual decrease in skill generally occurs, but ability is substantially maintained where interest and practise are present.

(2) Decrease in physical energy and power is to be expected, but increase in organization and judgment may compensate.

(3) Decrease occurs in obvious external activity rate when meeting new situations, but with appropriate enlargement of interests and growth through experience increase in adequate integration of mental powers may be achieved.

If you could see the people themselves as they file by the psychological camera the significance of these conclusions would strike you, as it has me, with compelling force. Each of the two thousand persons who has so generously cooperated in the experiment has given, in a two- or three-hour period, a pretty clearly sketched picture of his or her mental make-up, mental habits, capacities, interests and skills. I wish you could see the great procession of these interesting human beings, including as they do people of every kind of talent and aptitude. They are representative of people in general except in one respect: they do not include unfriendly, uncooperative per-

sons, because all of these people wanted to help in this big experiment.

The personal identity of my cooperators must be guarded and the individual records are strictly confidential, but I am going to tell you a little about a typical person or persons in each of the different decades.

Here comes, first of all, the young man of 20; he is fond of activity, works well and persistently. His eyesight is good, his stand steady. His reaction time is quick, whether in old or new directions. He can turn quickly and effectively from one type of work to another. He is vigorous and enthusiastic, ready and eager for the task before him.

At 30 he seems much as he did at 20, except that he is somewhat steadier and more skilful in his chosen work. His interests are more definitely settled and he recognizes his own capacity more clearly. He is either continuing to extend his learning to include wider aspects of his work and more varied cultural and recreational possibilities or else settling into a routine of daily work and play suited to his present age but without the preparatory stages of cultural life interests which he will need later on.

Although there is this relatively slight difference at 30, two type men are pretty clearly defined at 40. The first is the man whom we saw at 30 skilful and steady in his work, and with interests broadening to include wider fields. He is as capable as ever in managing most kinds of material, just a little slower and more cautious in his reactions—for example, more careful in driving his car. He is somewhat more interested in getting on with his associates in a friendly way. He devotes time to reading and to thoughtful conversation about important problems. He knows about present events and the progress of science, politics, philanthropy, art or religion.

The other typical man of 40 is the man of routine who has changed comfortably in the direction of decline. He has added no new interests and skills and in those that he had, that inevitable physiological decline of age is beginning to appear. He dimly recognizes that he is slipping a bit and that the new is some way annoying to him; at times he pushes himself and tries to react as quickly as when young and thus sacrifices adequacy and appropriateness to speed. In temperament he becomes more irritable.

At 50 and a little more markedly at 60 each of the two types shows somewhat less clearness in vision, and a decrease noted in the speed of hand and foot is characteristic. Still the much practised skills are near the maximum in most cases, because usually in these experience compensates for the slight physical slowing down that has occurred. The representatives of the professions and occupations most dependent on physical power and bodily strength, including such widely diverse activities as truck driving, baseball playing and dentistry, feel the decrement most and most need the secondary interests and skills which they may, if they were wise, have developed outside the routine work which they follow to make a living. If they did not do this we see them now, as their manual and general physical skill declines, resorting to a life of fancy, telling of their old exploits and forgetting the present as they live over the past.

At 70 and at 80 we see those who in the earlier decades built out their interests and developed their skills not only for the immediate business of the day but also for the years when these skills tend to wane, as the counselors and advisers of younger men who have speed and dexterity but lack the experience of long years. To the fruits of their ripe maturity Cicero's remarks two thousand years ago apply: "Great actions are not achieved by exertions of strength, or speed, or by quick movement of bodies, but by talent, authority, judgment; of

which faculties old age is usually so far from being deprived, that it is even improved in them—." These counselors are really still young in the sense that youth means growth and development. Old are the men of 70 and 80 who had little or no interest beyond matters in relation to which age brings marked physical decline.

While the successive decades beyond the age of 30 years show for most things thus far measured, slow progressive decline in the averages, still there is really a large amount of person-to-person difference when we consider the scores of individuals. About 25 per cent. of men between the ages of 50 and 70 can perform mental and light manual tasks as well or better than average men 20 to 50 years of age; and fully 10 per cent. of to 70- to 90-year group can perform mental tasks as well or better than the average of the 20- to 50-year group. The large amount of overlapping in the abilities of successive ten- or twenty-year periods may give great hopes to all of us.

Of course, health plays a big part all through the years, but the training of mind which prepares for change may often diminish the influence of declining health. And so we may occasionally see the hale and vigorous 80- or 90-year-old participating with weight in the deliberations of community and state; contributing valuably from the experience and through the insight acquired in long years.

Only typical individuals have been described and this brief review has been limited to the men. The trends hold true for the women also, and I wish time would permit me to tell you now about them as they have been at least equally cooperative in going through our tests and measurements. I want here again to emphasize the fact that individual differences in both interests and skills are more conspicuous among both men and women than are age differences. Some of our oldest people can turn out better work than the average man or woman in early adulthood. The importance of this fact for industry and employment of all kinds is obvious. If the best utilization of the best abilities of human beings is to be made there can be no old age retirement dead-line. The individual and his actual contribution, not his age by the calendar, will eventually become our employment criterion.

In conclusion, we may say that maintenance of our mental abilities will not take place automatically. What each of us needs to do is pretty clear. We must adopt a maintenance attitude and recognizing that modern industry, and many of the professions, now more than ever, fail to fill up our time and to provide for full and continuous mental development, we must seek additional life avenues suitable to our individual interests and capacities.

(1) As our skill inevitably declines, but does so least where interest and practise are present, we must bestir ourselves with effective exercise along the special lines where we wish the decline to be least rapid.

(2) We may anticipate and compensate for the decrease in physical energy and power by early and continued efforts toward organization and the substitution of good judgment for bodily speed and strength.

(3) Since decrease is bound to occur in the obvious external activity involved in meeting new situations it becomes tremendously important to develop a wide range of interests and wide fields of knowledge so that there may be more places where effective integration and growth through experience may occur.

Aristotle said "Education is the best provision for the journey to old age," and we may add that there is no more important or interesting science of strategy than that required for the happy conduct of this journey.

# MAN BEFORE THE DAWN OF HISTORY

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A NUMBER of years ago I saw in the British Museum a vase from Mesopotamia with an accompanying card giving its age as 4500 B. C. It was the oldest dated object I saw in the museum on that visit. I gazed at it long in contemplation—6,500 years old—it was difficult to believe, but that was before I became interested in prehistory. Since then I have held in my hand a crude stone object known as a hand-axe or coup-de-poing that was found in England and that by the accepted criteria of prehistoric science is from 200,000 to 500,000 years old.

What evidence have we that man's antiquity goes back to a time of such inconceivable remoteness? The evidence is in the main of four kinds. First, the discovery of man-made objects or artifacts in ancient strata that are geologically datable with reasonable accuracy. Thus J. Reid Moir has found flint tools imbedded in the Red Crag of East Anglia, a geologic stratum which, overlaid by a number of later deposits, may well be between half a million and a million years old. Secondly, parts of human skeletons have been found in layers belonging to the so-called Pleistocene epoch. The most recent of these finds and perhaps the most important of all is the completely petrified Chinese skull imbedded in a solid layer of travertine. From its depth below the surface and from other dependable criteria the age of this layer is estimated at a million years. Then, human remains, human tools and human works of art—sculptures and paintings—have been found in Europe in association with the saber-toothed tiger, the woolly mammoth, the rhinoceros, the lion, the reindeer and the cave bear—animals belonging to an era long, long past in central Europe.[1] Finally, apart from any geologic or stratigraphic evidence one can not contemplate the artistry of the cave-dwellers without feeling that an immensity of time must have elapsed from the first appearance of man on the earth until such astounding skill was attained. No longer can we consider the Babylonians or the Cretans as very ancient peoples. The first dynasty of Egypt, that of Menes, 4700 B. C., Tutankhamen, Solomon, Assurnasirpal are of yesterday, and patient Bishop Ussher was quite mistaken when after a laborious calculation he decided that the world had been created on October 9, 4004 B. C.

I shall not go into the details of the geologic time-table accepted by scientists but will merely point out that primitive man, speaking chronologically, lived in the epoch called Pleistocene or Quaternary, which is the age that directly precedes the present called the Psychozoic or Age of Man. The beginning of the Pleistocene goes back from 200,000 to 500,000 years. Preceding it is the so-called Tertiary, a geologic period of vast length during which the large land animals appeared.

We are greatly helped in differentiating successive "cultures" or eras of prehistoric man by a study of his tools. It would be extremely interesting to know how early in mundane time man began to make tools and other implements. The first tools were probably made of wood,

[1] Individual mammals of extinct species may have survived long beyond the time of the main stem of that species so that the finding of fossil mammoth or tiger bones, for example, does not warrant the conclusion that the contemporary humans go back to the time when these animals flourished in greatest number.

but they have not been preserved. Very early, however, man learned to use flint and other hard stone and to fashion them to his hand in a crude way by chipping. The resulting implements are relatively abundant and can be gathered in many places in Europe by a little digging beneath the surface and in caves and cliff hollows. In the oldest layers they are crudely chipped, but as we proceed to younger strata we find better and better workmanship. The French, who have so far done the most extensive work in prehistory, have used the stone implements as a basis for a systematic classification that is now generally adopted throughout the world. The names given are chiefly those of French towns or places where the particular type of stone culture or industry finds its best illustration. These are from above downward, that is, from the most recent to the oldest prehistoric age—Magdalenian, Solutrean, Aurignacian, Mousterian, Acheulian, Chellean, Prechellean. The series as a whole is known as the Old Stone Age or Paleozoic. The stone implements were made by chipping, hence they are rough. In the succeeding New Stone Age or Neolithic, they are smooth and polished.

Geologically, the Old Stone Age coincides largely with the Pleistocene epoch, a period during which occurred those tremendous glaciations or Ice Ages that swept down from the Arctic regions and covered vast areas of North America and Europe. Through Charpentier and Agassiz and their successors we know how profoundly the Ice Age has affected the present-day landscape as well as the fauna and flora of the temperate zone. The individual ice ages were separated by warm interglacial periods, during which the land was habitable. Evidence is accumulating that man was unquestionably living on the earth in the first interglacial period; and there is good reason for believing that he existed long before—in the Pliocene, the last epoch of the Tertiary.

Before I speak in detail of the Men of the Old Stone Age and their handiwork as it can be seen in the South of France, I want to discuss briefly the short annals of the science of prehistory. Fossils had been known since the time of Herodotus, but their meaning was not guessed until Leonardo da Vinci, the omniscient, recognized in them the petrified remains of once living organisms. But, like much else the fertile Leonardian brain suggested, the matter of fossils was forgotten. Johann Berringer, the Wurzburg professor in the eighteenth century, looked upon them as objects placed in the ground by God himself to test the faith of man. When John Frere, in 1797, found in an ancient brick field in Suffolk, England, some hand-shaped flints and recognized them as human products, no one paid any attention to him. Dean Buckland, reader in geology at Oxford, in 1822 found in a cave at Paviland in Wales the remains of the rhinoceros, the cave bear and other extinct animals side by side with human bones. He attributed their joint presence to the Deluge. This reminds one of Asa Gray's explanation for the extinction of the mastodon —it was too big to go into the Ark.

In 1826 the Reverend Dr. T. MacEnery, a Catholic priest, found similar fossil remains in Torquay, in association with stone implements. He drew the correct conclusion that man must have lived in England contemporaneously with the mammoth and the rhinoceros, but he did not dare to publish these conclusions during his life, and they did not appear until sometime after his death.

In 1823 Boué sent to the celebrated Cuvier a human skeleton exhumed near the banks of the Rhine. Associated with it in the loess strata were remains of a number of extinct animals. Cuvier utterly failed to appreciate the significance of this discovery and rejected it

as being of no importance. Several other isolated finds of similar nature were made but challenged no one's interest. Then came a man who may well be called the father of prehistoric anthropology—Boucher de Perthes (1788–1868), director of customs at Abbeville. He found a number of what he called antediluvian axes and identified them as the work of an extinct race of man. Like Pasteur a generation later, he was ridiculed by the academicians. But those who derided him as a dreamer and ignoramus are forgotten while Boucher de Perthes is enthroned among the immortals.

Probably the most important date in prehistory is 1856, the year in which a modest German professor, Dr. C. Fuhlrott, found a skull cap and other human bones in a cave in the Neanderthal, near Düsseldorf on the Rhine. These bones, found as they were in association with those of animals of extinct species, created a sensation. Fuhlrott, Huxley, Lyell, King and Broca saw in them the remains of a primitive human type, but Virchow considered the peculiar appearances as due to disease, and by his great authority silenced his opponents. But as time passed similar finds were made elsewhere, particularly in Southwestern France, and we now know that they as well as the original Fuhlrott bones represent a widely disseminated race called after the place where the original skeleton was found, the race of the Neanderthals—*Homo Neanderthalensis*.

About 1894 Eugene Dubois, a Dutch army surgeon, discovered at Trinil, on the island of Java, the top of a skull, some teeth and a thigh bone which he believed were the remains of a sort of missing link and which he designated by the now famous name *Pithecanthropus erectus*. In close proximity he found parts of more than twenty-four species of mammals totally extinct. Although his discovery attracted world-wide attention, Dubois for many years absolutely refused to have any one see the originals, but recently he has become more complacent and has exhibited them to a number of scientific men, including Professor MacCurdy, of Yale.

The Java or Trinil man, as Pithecanthropus is also called, has evoked a great deal of discussion. The skull, as reconstructed by MacGregor, has a capacity of about 900 cc; that of modern man 1,500; that of the Indian Veddhas and of the Papuans of New Guinea 1,230 to 1,250 cc, while that of the highest ape has a content of only 600 cc. Thus the Pithecanthropus is about midway between the highest anthropoid and the lowest human. There is much discussion as to the geologic age to which Pithecanthropus should be assigned. Dietrich, Osborn, Elliot Smith and MacCurdy place the Trinil man in the Pleistocene period, but others, who find the associated animals to be of an earlier age, put Pithecanthropus in the Pliocene. A lower jaw fragment has recently been found some twenty-four miles distant from the spot where Pithecanthropus was discovered. If it belongs to a second individual of the same genus, it suggests that the Java man had a lower jaw of slight build and an almost vertical chin. The skull cap is marked by expansive, heavy brow ridges.

One of the most revered of prehistoric relics is the famous Heidelberg jaw found in 1909 by Professor Schoetensack in the Maurer sandpit near Heidelberg at a depth of 82 feet below the surface. It is not strictly a human jaw, for it is too large and possesses, besides other minor anthropoid characters, a strikingly receding chin. Its age is estimated at between five hundred thousand and a million and a quarter years.

In 1911–1912 Charles Dawson discovered near Piltdown, Sussex, an incomplete skull and lower jaw, which from many points of view constituted, until

1929 at least, one of the most important of all prehistoric discoveries. The skull is unquestionably human, with a brain capacity of 1,240 cc. The lower jaw, however, as one writer puts it, has been a bone of contention since its discovery. Some think it is too simian to belong to the Piltdown skull. Recent finds, however, in the same region make it highly probable that the jaw belongs to the skull and not to an anthropoid. Piltdown man, whom Woodward has designated *Eoanthropus dawsoni* (Dawnman), had a receding chin, prominent canine teeth and low brow ridges—he differed thus considerably from the Java man. In close association with the Piltdown skull Dawson found a quantity of flints, crudely chipped, which he called Eoliths, believing them to be the handiwork of the Piltdown race. Many have disagreed with him, attributing the chipping to natural breakage, but belief is growing, largely through the investigations of J. Reid Moir of Ipswich, that they are true artifacts. Although placed at first in the Pleistocene, Sir Arthur Keith, Newton, Dawson and others are convinced that Piltdown man is of Pliocene age, a conclusion that places early man in England at a time of enormous remoteness. And if we accept the mute testimony of the Eoliths taken from exceedingly deep geologic strata in England, then the recently announced estimate of Professor Hooton that man goes back to the second half of the Pliocene, or about four million years, does not seem altogether out of reason.

In 1921, a skeleton of Neanderthal type was found in the Broken Hill mine in Rhodesia. More recently Professor Dart found at Taungs, northwest of Johannesburg, in a limestone cliff at a depth of 50 feet, the skull of a boy that possesses both human and simian characteristics. The name of *Australopithecanthropus africanus* has been given to this species. Since then other interesting finds have been made in Africa recalling the prediction of Darwin that Africa might be found to be the cradle of mankind.

Perhaps the most important recent African discoveries are those of Professor Reck and Mr. Leakey at Oldoway in Kenya Colony. Professor Reck had unearthed a skeleton of an apparently modern type man in 1913. If contemporary with the animals with whose petrified remains it was found, it indicates a very great age for *Homo sapiens*, at least in Africa. The matter is still in dispute, but the recent explorations of Mr. Leakey in Oldoway seem to bear out his contention that Professor Reck's skeleton is of lower Pleistocene age.

While an African origin for man is in the realm of the possible, the majority of scientific men lean to an Asiatic ancestry. Osborne and his associates in the American Museum have been consistent advocates of this view and have had its confirmation as one of the main objectives of their several expeditions into the Gobi Desert. Fortune was not with them, however, but instead smiled upon a young Chinese geologist named W. C. Pei, who on the last day of a season's excavations, on December 2, 1929, made the most famous of all prehistoric discoveries. Imbedded in travertine and completely petrified, he found an uncrushed skull of a woman. After careful study—it took months to remove the stony encasement—Professor Davidson Black, of the Peking Medical School, and Professor G. Elliot Smith came to the conclusion that the skull represents an early type somewhere between Trinil man and Piltdown man or even an earlier species. The thick skull has more massive brow ridges and a greater skull capacity than Pithecanthropus. Geologically, *Sinanthropus pekinensis* belongs, according to Father Teilhard de Chardin and Dr. C. C. Young, to the lower Pleistocene or Polyeene and may

easily have an antiquity of a million years. In a communication just received from Professor Elliot Smith he calls attention to the evidence discovered by Mr. Pei that Sinanthropus knew fire. Charred objects were found in deep travertine deposits. These startling discoveries of Mr. Pei have been confirmed by Abbé Breuil, who last October made the arduous journey to Peking for the purpose of studying the evidence accumulated with respect to Sinanthropus.

Abbé Breuil holds that *Sinanthropus pekinensis* is not the being devoid of human faculties that he was at first supposed to be in view of the approach of his skull to that of the Anthropoids, but despite his animal characters he is already "man," with a progressive intelligence and the beginning of supremacy over other animals by virtue of his knowledge of fire and of working in stone. He is by no means the last step toward humanity nor is he the first—the point of departure is much farther back. This man with his technique and practical science had numerous human ancestors, of whom we know absolutely nothing.

By the end of 1930 the finds in China had reached five jaw fragments and the same number of skull fragments, a large series of teeth, but curiously no human limb bones have so far been discovered. Large quantities of fossiliferous material, implements of bone, quartz and quartzite have also been found. We have no knowledge of the place where Pithecanthropus and Eoanthropus lived, the few broken fragments of their skeletons that have been found having been deposited either by running water in the gravel of a river-bed, as at Piltdown, or in the tufaceous bank of a stream, as in Java, but in the case of the Peking man, he must actually have lived in the cave where his petrified remains were found.

Within recent years many important discoveries in prehistory have been made in Czecho-Slovakia. In the summer of 1930, at the suggestion of Professor and Mrs. Absolon, the well-known prehistorians, I paid a visit to Brno (Brünn), the capital of Moravia. Here under the inspiration of Professor Absolon a splendid prehistoric exhibition called "Anthropos" was in progress. I had known something of the activity of the Czechs in prehistory, but I was in no way prepared for the wealth of recovered material I saw in Brno. There were enormous quantities of fossil remains of the mammoth, the tiger, the lion, the rhinoceros and also human skeletons, as well as flints and other stone artifacts of every conceivable kind.

While there has been some dispute as to the proper assignment of the Moravian culture, the majority of scientific men agree with Professor Absolon that it is Aurignacian. Unfortunately, the national pride of the Czechs, in a measure justified by the signal progress of their newly established republic, impels them to publish everything in their native language, which by its very looks frightens off those not born with a Slavic tongue.

While at Brno I decided to pay a visit to the Augustinian cloister of Gregor Mendel. As my guide in the "Anthropos" exposition, Mr. Skutilh, had himself never been there, he gladly volunteered to accompany me. Unhappily we arrived after twelve o'clock and were informed by the affable monk who received us that the Mendel apartments were closed at noon. However, he would see the abbot. This worthy successor of Mendel gave permission to open the hallowed rooms, enabling us to inspect Mendel's library, his microscope and many other relics. I then asked to see the garden, in the hope of finding living descendants of Mendel's famous peas. Not a single one remained, only a tall tree that he had planted. I got the impression that the cloister was not greatly

interested in Mendel's scientific work. On parting I casually inquired of our kind host whether they had many visitors. "Not many," he said. "Whence do most of them come?" His answer amazed me. "The majority," he said, "are Japanese."

Interesting finds have within recent years been made in Palestine. Miss Dorothy Garrod has found in the cave of Shukba a vast quantity of Neanderthal remains, among them a number of skulls from which pieces had been cut out, similar to the mutilated brain cases recovered from a quarry at Ehringsdorf near Weimar. The inference has been drawn, not unreasonably, that the holes were made by our cannibalistic ancestors for the purpose of extracting the brain. In the Shukba cave and in many other places long bones have been found that were evidently broken by a sharp instrument while in a fresh condition, apparently for the purpose of obtaining the marrow.

A number of startling discoveries have been made in Palestine since the beginning of this year. Professor MacCurdy informs me that nine skeletons of Neanderthal men have so far been found by Theodore D. McCown, of the British School of Archeology. Miss Dorothy Garrod believes that the skeletons are of Neanderthal type, although differing somewhat from the Neanderthal man of Western Europe. The hands have the characteristics of modern man, but the feet and thigh bones have not.

It is rather interesting that despite an almost feverish activity on the part of digging scholars the actual quantity of prehistoric human remains so far unearthed is comparatively small. The question naturally arises, "Why are the remains of early man and his precursors so rare?" Chiefly because primitive humans did not embalm or bury their dead. Consequently, the cadavers were devoured by wild beasts or rotted on the ground. You remember the grave-digger's answer when Hamlet asked him, "How long will a man lie in the earth ere he rot?" "In faith if he be not rotten before he die—as we have many pocky corses nowadays, that will scarce hold the laying in—he will last you some eight or nine years; a tanner will last you nine years." Shakespeare might be surprised to know that some bones interred accidentally or on purpose more than twenty thousand years ago have lasted until now. Survival, if one may use that word in connection with dead bones, probably depends upon the nature of the soil. The accidental fall into a river bed or in soft mud could easily bring about the preservation and fossilization of isolated skeletons or skeletal parts. Man, however, seems to have begun quite early to bury his dead, certainly in the latter part of the Old Stone Age, thus helping to preserve for us a number of skeletons of inestimable value to the science of prehistory.

I ought not to pass over in a historic retrospect the year 1859, which witnessed the appearance of Darwin's "Origin of Species." Sir Arthur Keith, in his presidential address at last year's meeting of the British Association, reemphasized in strong anti-Daytonian phrases the important bearing of Darwin's work upon the study and comprehension of the descent of man.

I now want to take the reader to France, for it is there that the prehistorian finds more to interest him than anywhere else in the world. While a large part of France is rich in prehistoric sites or stations, as they are called, the real capital of the prehistoric world is the pleasant little town of Les Eyzies in the Dordogne. Through the courtesy of Professor George Grant MacCurdy, director of the American School for Prehistoric Studies, I was enabled while in Europe to join the school for a brief stay in the romantic village of Saint Léon-

sur-Vézère. The Vézère, a tributary of the Dordogne, is a silent dreamy river. Standing on its banks I had an overpowering sense of mystery—I was conscious of an antiquity with which that of the Roman Forum and the Egyptian Pyramids can not be compared. There is a fine little museum in Les Eyzies, containing quantities of artifacts and human fossils found in the region. The town is also noteworthy for its war monument, which is one of the best I have seen. The artist with an understanding of the genius loci has carved upon the granite boulder a youth who with one hand crushes a prehistoric bison and with the other strangles a German eagle.

In the vicinity of Les Eyzies are a number of world-renowned prehistoric caves which penetrate deeply into the hillsides and must have afforded a wonderful shelter for the cave man. I can not in words describe the impression made upon me by the pictures painted and graven on the walls in those caves. Only once before in my life did I have a similar experience—at my first sight of Saturn through a telescope.

In the "Prometheus Bound" of Aeschylus I discovered an interesting passage that shows how profound and true a conception the poet had of the primeval life of man, a conception that did not again rise into man's consciousness until 2,400 years later. He says, "Knowledge had they neither of houses built of bricks and turned to face the sun, nor yet of work in wood; but dwelt beneath the ground like swarming ants, in sunless caves, ἐν μυχοῖς ἀνηλίοις."

All the caves are interesting, and each has a character of its own. Among the most thrilling is the one called Grotte des Combarelles. There is a small fee for admission. Three of us entered, guided by a peasant woman, who knew her story and rattled it off remarkably well. We carried flat sticks with a tallow candle at the end. The floor of the cave is muddy and slippery, the walls come close, the ceiling is so low in places that we had to crouch for long stretches. From the entrance until we stopped to turn back was about one thousand feet. Through that whole length both walls are covered with drawings in black and white of animals—the reindeer, the mammoth, the cave bear, a species of horse, the bison, all done with an overwhelming realism. A few strokes indicate that the mammoth was woolly. From the Grotte de Combarelles we went to the equally interesting Font de Gaume. This particular cave belongs to the local laird, who has had it electrically wired. It too contains many vividly artistic drawings, some in colors. Many of the pictures in Combarelles and in Font de Gaume have become well-known through reproductions. Although fewer are in polychrome than in the famous cave of Altamira in Spain, in artistic finish and realistic expression they are no less striking.

Who were the men who made those wonderful life-like drawings, unrivaled in their fidelity to nature? How were they able to draw and to carve so skilfully in the depths of a damp and sunless cave? What motives prompted them to what must have been slow and gruelling labor? These and other questions passed through my mind as I gazed upon the pictures. The first question may be answered by saying that the cave painting race belonged to the later Paleolithic epoch, to the Aurignacian and Magdalenian, also called the Age of the Reindeer, of which the Cromagnon is the most imposing representative. He was of good stature, had a fine head, and in practically every physical respect, and we must presume in mentality, the first to deserve Linné's designation of *Homo sapiens*. On the other hand, Mousterian man, his predecessor—how far removed in time we do not know precisely—was

an inferior being, prehuman in the anatomic and cultural sense.

Prehistorians were for a long time puzzled as to what sort of light the Aurignacian artist employed during his work. There is nowhere any evidence of soot. It is conjectured that he used an animal oil, either on a torch or in a shallow dish like that used by the Eskimos, as pointed out by Sollas and by Hauser. Much has been written as to the possible motives of the painters and sculptors. Was it art for art's sake? The majority of writers do not think so. They look upon the painting and sculpture as motivated by magic or sorcery. One of the pictures of a man disguised as a beast is strongly suggestive of this. Moved by theurgic beliefs that graphic representation of an object could give control over it through magic, they may have drawn images of the beasts that served them as food so as to promote fecundity. This idea is brought out in the novel called "Bison of Clay," by the son of the well-known prehistorian, Count Beguën. It may account for the fact that by far the greatest number of animals pictured are food animals. On the other hand, the same magical control might be secured over dreaded beasts of prey by similar means, that is, by visible representation. Such beliefs prevail among primitive peoples to-day and even among some that are looked upon as civilized.

If pictorial representation was used to promote fertility, the rarity of the human figure on the cave walls might perhaps be explained as a sort of Paleolithic birth control. Under the conditions of life in the cave—not unlike those prevailing in this era of grace—every additional mouth to feed was an unwelcome burden. The few human figures that have been found are chiefly those of the female, and are far less artistic than the animal pictures. They have small heads, large, pendulous breasts and huge buttocks, like the Hottentots. Is this figure a mythical or symbolic expression of fecundity or is it a realistic representation of the Aurignacian Venus?

As an amateur I ought perhaps not to express an opinion, but I could not escape the feeling that the cave art as well as the engraved bone and stone implements and ornaments represent a real urge for artistic expression, a hypothesis that does not contravene or exclude other motives.

Primitive man made use also of another kind of protected home, the so-called rock shelters, deep natural excavations in the sides of cliffs. A typical rock shelter is that of Laugerie-Basse, which is quite extraordinary in that it is possible to identify in its superimposed layers nearly all the old stone epochs. The thin compressed strata remind one of a layer cake, with layers rich in relics separated by sterile ones. In Laugerie-Basse, as almost nowhere else, one can trace without interruption all the ages of man in France—the Paleolithic, the Neolithic, the Gallo-Roman, the Middle Ages, and the present. Few places in the world have been inhabited by man for so many thousands of years without interruption.

Before leaving the Les Eyzies region we paid a brief visit to the village of Cromagnon, one of the holy places of anthropology, for it was here the famous Cromagnon man was discovered in 1868, during the construction of a railroad. There is, however, little of interest left in the sparsely settled village. Recently a statue has been erected at Les Eyzies to represent the Old Man of Cromagnon. It does not picture him as an Adonis; the long-armed slouching gorilla-like figure hardly suggests the talented painter of Font de Gaume or Combarelles. But after all the artist's fancy has nothing to do with unrecoverable reality.

Buried skeletons of a race similar to

the men of Cromagnon but shorter in stature have been found in considerable number at Grimaldi near Mentone. The physical characters of the Grimaldi race are suggestive of a negroid admixture—this is also true of the taller race—which is not surprising in view of the probability of the existence of a land bridge to Africa in prehistoric times. Sir Arthur Keith, I may add, does not believe that Cromagnons had negroid characters because they were hybrids. As a "Unitarian" he would explain the evolution of the human race on the basis of a common ancestor, and that it was only after dispersion that the differentiation occurred into the black, yellow and white races of mankind.

The Cromagnons or Aurignacians lived in Europe not later than 20,000 years ago. They seem to have migrated into Europe, for until the end of Mousterian time Europe was inhabited by the Neanderthals. The Aurignacian tools and implements are of far higher order than those of the preceding Mousterian. Cromagnon man, according to MacCurdy, was the first to reach the stage of making tertiary tools, that is, tools requiring the use of primary—found ready to hand—and secondary tools for their manufacture. They were used for an ultimate purpose other than tool making. The Solutrean industry, although later in time, is marked by a perceptible decline in art, except in one respect—the spear points and harpoons show a workmanship that for sheer beauty and symmetry can not be matched by the most skilful artisan of to-day. The laurel leaf and willow leaf flints of Solutré are a joy to behold. Recently a number of implements made of rock crystal have also been found.

The Aurignacian and Magdalenian man had also begun to make ornaments—pendants and beautifully carved commander sticks (*baton de commandement*). No doubt he made use of wood in many ways, but those utensils naturally have not been preserved. Old Stone man apparently had no writing; a few linear strokes upon tools and weapons may indicate an idea of number. The inscribed tablets of Glozel,[2] which some refer to the Magdalenian period, are of questionable authenticity.

What about our own continent? Ancient human remains have been found in America, but whenever it was possible to determine their ethnographic position, they turned out to be Indian of the same type as that now living. No doubt man has been on this continent for many ages, but the human remains are not like those of primitive man in Europe. Quite recently Cook and Hay have found in Folsom, Nebraska, and in Colorado, in strata that they identify as Pleistocene, flint artifacts in association with the bones of extinct mammals—bison, lion, elephant, etc. Whether the conclusion is warranted that the makers of these artifacts and the now extinct mammals were contemporary can not be definitely stated at this time, but a number of paleontologists do not agree with Cook's ideas as to the age of Folsom culture and agree with Hrdlička that no evidence of prehistoric man in the European sense has ever been found in this country. The famous tooth, which was first considered to be the relic of Osborne's *Hesperopithecus haroldcookii*, later was admitted by Osborne and by Gregory to be the tooth of a peccary, an extinct species of pig. Edgar B. Howard, of the University of Pennsylvania Museum, has made some interesting finds bearing on the question of American prehistory in the Guadalupe Mountains, and only a few days ago the statement was telegraphed from Florida that an arrow head had been found in a mammoth skull. The implications of these things are so far-reaching that we must know more about them before drawing any conclusions.

After a lapse of time similar to that

[2] Riesman, "The Story of Glozel," *Science*, lxxii, 1858, pp. 127–131, August 8, 1930.

which separates us from the cave man of Europe, what will *Homo sapientior* think of us of the twentieth century, of our wars and hatreds, our economic and political ineptitude, our want and suffering in the midst of plenty? Will he place us in culture nearer to the Cro-magnon than to himself? Who can guess? But no matter how dark the immediate future may appear, man's past achievements are colossal and an earnest of an infinitely greater civilization, the full possibilities of which are beyond our present imagination.

# NATIVE BIRD TRAPS OF FRENCH INDO-CHINA

By Dr. JOSSELYN VAN TYNE
CURATOR OF BIRDS, MUSEUM, UNIVERSITY OF MICHIGAN

WHILE collecting birds in French Indo-China in 1929 with the Kelley-Roosevelts' expedition I was much impressed with the skill and ingenuity shown by the natives in trapping wild birds. Although certain inherent difficulties prevented much progress, it was possible to learn the details of some of their methods.

I am indebted to Mr. Stephen C. Simms, director of the Field Museum of Natural History, for his kind permission to publish this material and to use the photographs secured by the museum's expedition. Miss Grace Eager, staff artist of the University of Michigan Museum of Zoology, has skilfully interpreted my rough field sketches.

### PITTA LIVE-TRAP

The Thai hunters of Muong Moun, Tonkin, were very fond of the meat of the large brown pittas of the region (*Pitta soror* and *Pitta nepalensis*), but when we offered the exorbitant bounty of twelve cents apiece for that special desideratum, they apparently brought us all their catch. Although pittas were

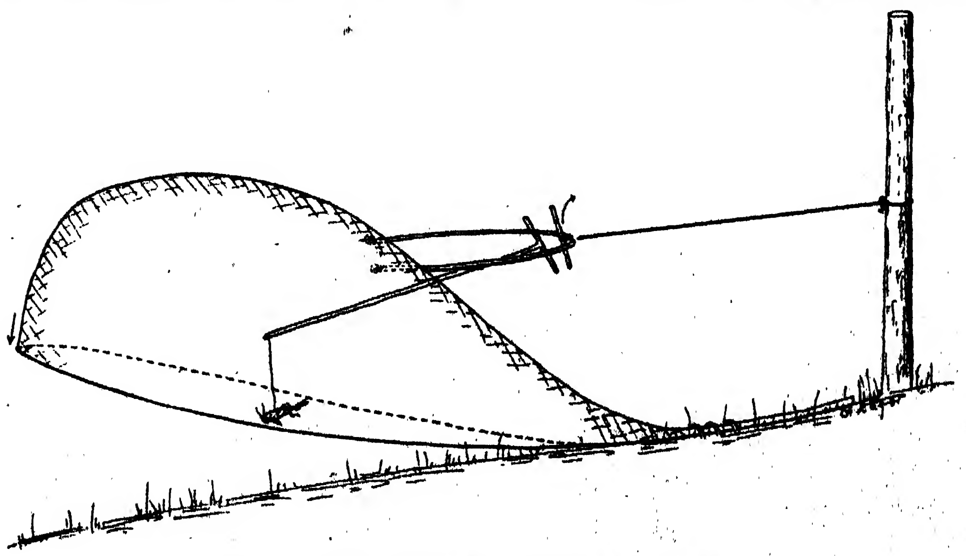


FIG. 1. PITTA LIVE-TRAP. MUONG MOUN, TONKIN.

so shy and secretive that we almost never shot or even saw one, the natives trapped and brought us twenty-eight in three weeks. When we asked through interpreters to be told the secret of their trapping methods, they refused, thinking that we wanted to do our own trapping and so save money. It was only when we were about to leave and had stopped buying pittas that they consented to show us how it was done.

As shown in Fig. 1, their pitta traps were essentially "box traps" made of split bamboo basket-work. The ends of the bamboo splints which extended from the base of the basket were pegged flat against the ground, thus forming a very effective spring to snap the basket down when the trigger released the supporting cord. When set, the front edge of the trap was held about six inches above the ground, exposing the bait in plain view to any unsuspecting pitta that might come down the little runway which led past the trap. A native showed me two such traps set about fifty feet apart in a little grove of second-growth beside a stream just beyond the limits of the village. One was baited with a live cricket and the other

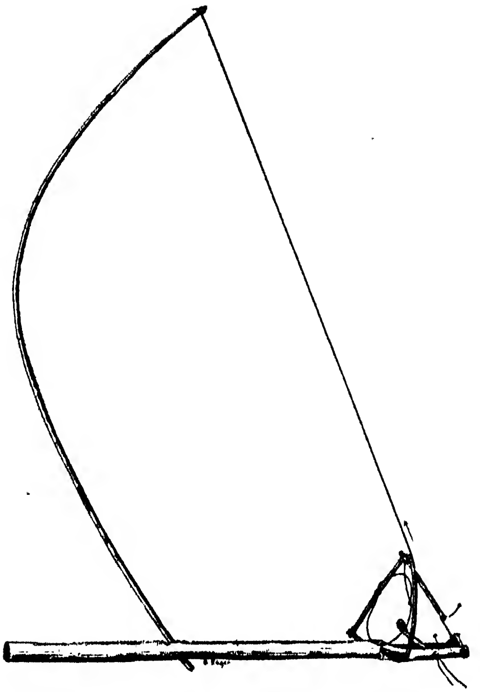


FIG. 2. PORTABLE SPRING-SNARE. PHONG SALY, LAOS.

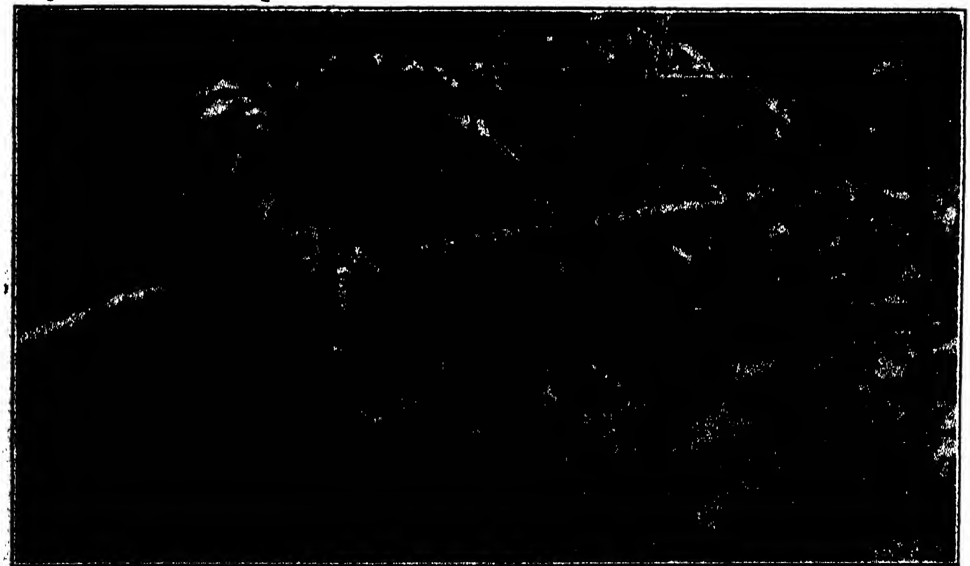


FIG. 3. PHEASANT DEADFALL NEAR MAKOMEN, LAOS.

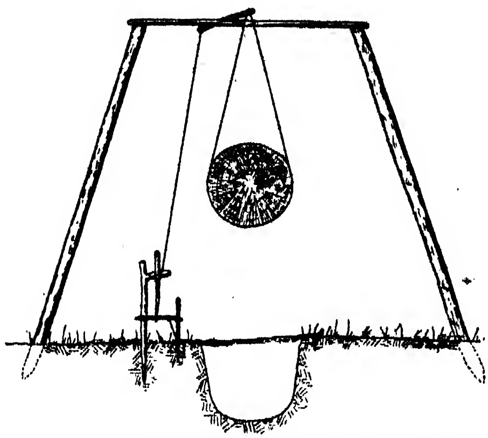


FIG. 4. PHEASANT DEADFALL MECHANISM. MUONG MOUN, TONKIN.

with a tiny live frog suspended by a thread about its waist.

### PORTABLE SPRING-SNARE

The only elaborate portable trap noted was this ingenious demountable trap commonly used by the Pu Noi hunters of Phong Saly, Laos. The drawing (Fig. 2) shows the trap set. A bright berry is caught in the adjustable loop at the end of the trigger and then the trap is set in the grass in such a way that a bird can approach only from the side toward the spring and has to reach through the noose to get the berry. As indicated in the drawing, the spring stick (usually about 28 inches in length) is merely set in a hole in the bamboo foundation stick and is held in place by the tension on the cord attached to its end. To fold the trap, the spring stick is first unshipped and then inserted into the hollow end of the foundation stick, so that in the folded trap the foundation stick forms a sort of scabbard for the spring stick. The fiber triangle which surrounds the noose is then folded flat against the foundation stick and the trap has become a straight, compact object readily transported. In fact, we often saw Pu Noi hunters carrying large bundles of these folded traps.

### DEADFALL TRAP

Near the Thai village of Moung Moun, Tonkin, I saw an interesting series of deadfalls in a little grove of bamboo. There was a series of five deadfalls in a row, spaced at intervals of about thirty feet and connected by a little bamboo stockade some two feet high. The stockade extended across a narrow neck in the grove and the only gaps in this fence were the five guarded by deadfall sets arranged as shown in Fig. 4. The deadfall logs were five or six inches in diameter and quite heavy. When released the log was arranged to fall into a trench of just sufficient size to hold it. When setting the deadfall, the native trapper had completely hidden the trench by a cleverly arranged false floor constructed of twigs and leaves. These traps, we were told, were designed especially for pheasants, but

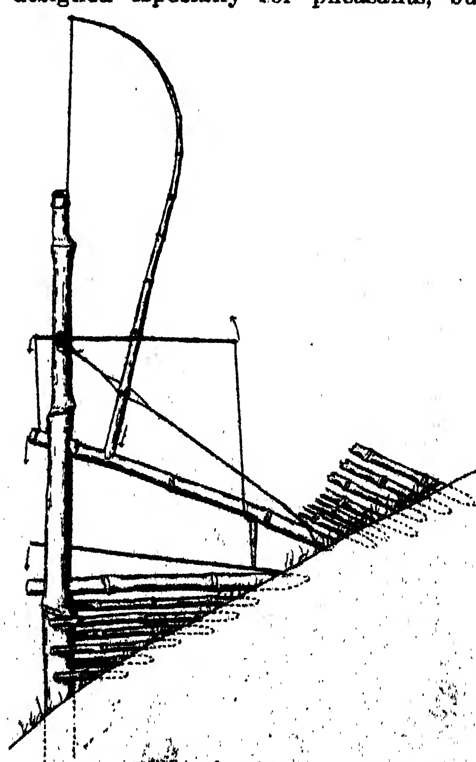


FIG. 5. SCISSORS-TYPE TRAP. MAKOMEN, LAOS.

we also found a bittern (*Gorsachius melanolophus*) and a large porcupine in this set. The three common pheasants of the region were the silver pheasant (*Gennaeus nycthemerus*), the jungle fowl (*Gallus gallus*) and the peacock-pheasant (*Polyplectron bicalcaratum*).

My companion, Russell Hendee, found another such series of deadfalls set by the Pu Noi hunters of the village of Makomen (near Phong Saly), Laos (Fig. 3). I was not able to examine the Pu Noi traps, but, judging from Hendee's photographs, they seem to differ but slightly in the method of suspending the log.

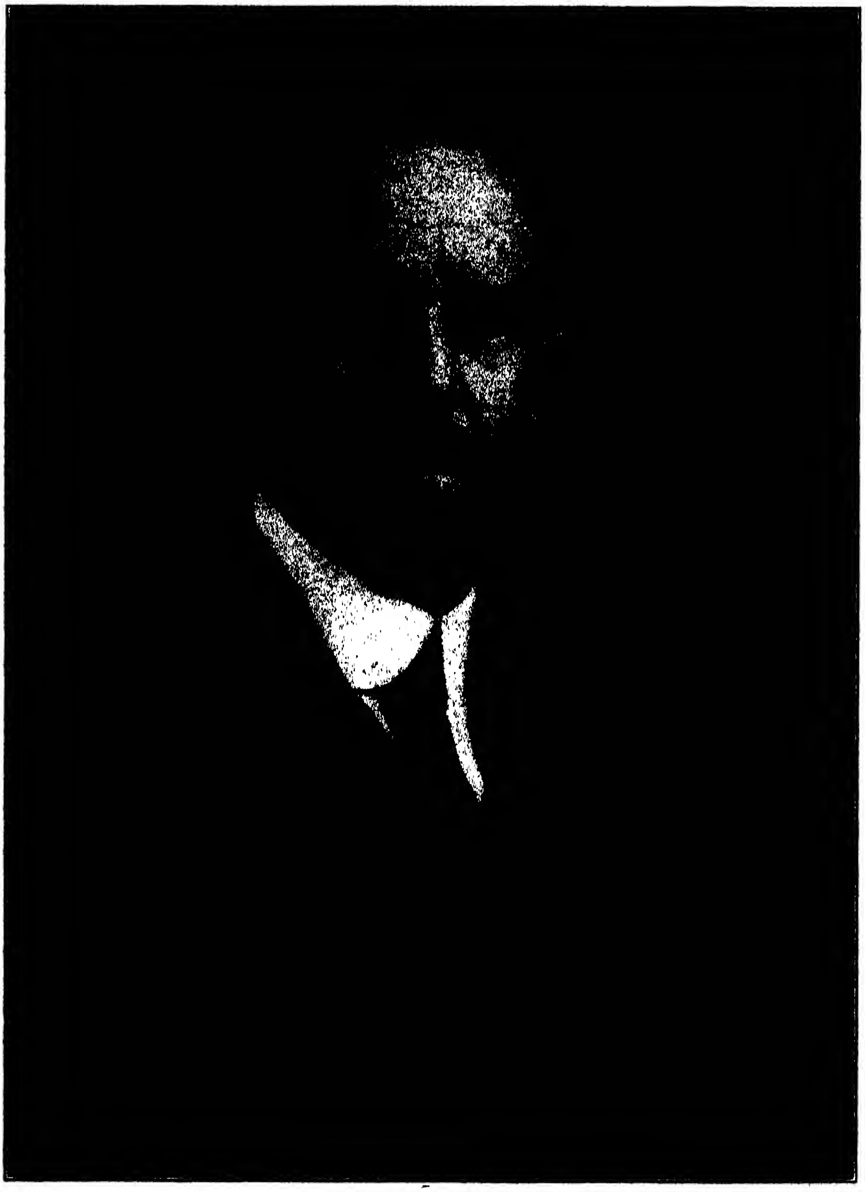
An excellent photograph of a similar pheasant deadfall as used in Burma was published by Beebe in his "Monograph of the Pheasants" (2, p. 84). It is interesting to note that Macpherson in his "History of Fowling" (1897) devotes the greater part of two chapters to an account of methods used throughout the world for catching pheasants, but barely mentions the use of pheasant deadfalls "in certain districts."

### Scissors-type Trap

Perhaps the most interesting of all was the scissors-type trap (Fig. 5) found in a wooded ravine between Makomen and Phong Saly, Laos. Set across a little game trail which ran along the slope of the ravine, the paling above and the cut-bank below, left the bird or mammal wishing to pass no easy choice but to pass through the hole in the trap. A peculiar feature of this trap is that the usual method of arranging the bamboo spring is completely reversed. It was no longer in use when I saw it and I could not learn from the natives about its use, but from the lightness of its construction it was obviously meant only for birds or very small mammals.

This trap is essentially similar to a Philippine trap figured by MacGregor and Gardner,[1] a fact which suggests one of the reasons for placing on record such fragmentary data as are contained in this paper.

[1] *Condor*, 32: 95, 1930.



THOMAS HUNT MORGAN

# THE PROGRESS OF SCIENCE

## THOMAS HUNT MORGAN, NOBEL LAUREATE

The award of the Nobel Prize to Thomas Hunt Morgan, in recognition of his fundamental work in genetics, will be received with satisfaction by all investigators in genetics, and by every one who is intelligently interested in heredity and variation or in the advancement of sound knowledge in biology. Morgan's work has laid a foundation on which all further development of knowledge of heredity, variation and evolution must rest. And he and his associates have constructed on this foundation a great edifice of detailed knowledge and understanding; a body of knowledge that has wide implications for the life of man and for general biological theory.

The thoroughgoing investigation of a single species, the fruit-fly, *Drosophila melanogaster*, has contributed most to this knowledge, although Morgan's work has ranged over many other fields. He is the experimentalist *par excellence*, an unwearied, driving worker, tenacious of purpose, following the objective evidence to the end, and courageously (at times audaciously) drawing the conclusions to which it leads—sometimes in face of universally opposing opinion—with a sureness that is justified by later developments. He has gathered a group of brilliant associates who carry on his methods and share in the discoveries that they yield. His methods of work, even in detail, have indeed spread throughout the world. So thorough has been the analysis of Drosophila that this organism now forms an unrivalled instrument for the solution of problems in heredity, variation and development. It is now worked on, further developing Morgan's methods, in many laboratories in every country of the world where biological knowledge is cultivated; it continues to yield results of fundamental interest.

The writings of Morgan and his associates include a great number of scientific memoirs, largely published by the Carnegie Institution of Washington, and many influential books in which the results of their investigations are summarized and brought into relation with the rest of biological knowledge. Morgan's scientific interests have not been limited to genetics; experimental embryology was his first love, and to this he returns at intervals. He has made extensive and important contributions in this field, including a number of books on the subject.

For many years he was professor of experimental zoology at Columbia University. Since 1928 he has been professor of biology and director of the William G. Kerckhoff Biological Laboratories of the California Institute of Technology. Much of his work has been done at the Marine Biological Laboratory at Woods Hole, Mass., where for many years he has been a member of the staff.

Morgan's associates know him as a man of strong individuality, with crisp, vigorous and humorous speech, and with sharply defined opinions that are quickly and forcibly expressed, but readily changed as objective knowledge increases. His work has not lacked recognition. Within the last five years he has been president of the National Academy of Sciences, president of the American Association for the Advancement of Science and president of the last International Congress of Genetics. To this group of high distinctions is now appropriately joined the Nobel Prize.

H. S. Jennings

ALFRED NOBEL

## THE CENTENARY OF ALFRED NOBEL'S BIRTH

In October of this year there was celebrated in Stockholm the centenary of a man whose name is familiar the world over in connection with the magnificent legacy he left in the interest of human advancement. The man is Alfred Nobel, the founder of the Nobel Prizes awarded in science and literature, and for peace. While most widely known for that posthumous benefaction, his name also carries other associations, for Nobel spent his life in scientific pursuits and made a number of important discoveries, among which that of dynamite became epoch-making. His life-work and legacy were integrated into one continuous unselfish service to mankind by the fact that the latter represented practically his total accumulated earnings on the exploitation of his inventions.

Alfred Nobel was born in Stockholm on October 21, 1833, coming of an old Swedish family descended in the distaff line from the famous seventeenth century naturalist and mechanical genius, Olof Rudbeck. His father, Immanuel Nobel, an architect and instructor in mechanical drawing, became noted in Sweden as an inventor, but because of financial reverses emigrated to Russia, where he established a workshop in St. Petersburg. He invented, among other things, a submarine mine, and soon became purveyor of ordnance to the Russian Government, which position brought him affluence.

As a young boy Alfred followed his father to the Russian capital where he received a careful education, which was complemented by a trip to the United States, about 1850, and advanced studies in Paris. On his return to St. Petersburg, he was employed, together with his brothers, in his father's workshop. His chosen field was chemistry, and influenced by the nature of his father's business he now began to devote himself to research in explosives. His attention was drawn to the recently discovered nitroglycerin, and especially in the years 1862 and 1863 he was engaged in attempts to produce that unstable substance for use as an explosive in blasting. In that connection he worked out the principle of initiating detonation, first constructing a powder and fuse igniter, and later, in 1865, devising the percussion cap. By introducing initiating detonation he laid the foundation of modern blasting technique.

In 1863, in the midst of these activities, he returned to Sweden where his father had preceded him after government orders had ceased with the close of the Crimean War. There he joined his father and brothers in attempts to introduce nitroglycerin in ordinary blasting and mining operations. In 1864 their laboratory at Heleneborg blew up, and his brother, Emil, was killed in the explosion. Undaunted by even so terrifying a disaster, Alfred pushed on and succeeded in forming a Swedish company to exploit his inventions and especially to manufacture nitroglycerin on a commercial scale. Success favored him, and in 1865 a factory for the purpose was completed outside Stockholm and another erected at Krummel near Hamburg.

Nitroglycerin was now a commercial article, but since accidents frequently occurred in its transportation, Nobel set himself the task of making it safe to handle, solving it in 1866 by causing nitroglycerin to be absorbed in infusorial earth, thus forming a solid substance. He had invented dynamite. Among his later epoch-making inventions may be mentioned gelatine dynamite, in 1875, and "ballistit" or "Nobel powder," between 1888 and 1889.

Even in his declining years Nobel remained active in research, and after having moved his residence to San Remo, in 1890, he brought his laboratory with him. There his days ended on December 10, 1896.

It may seem a contradiction in the life of Alfred Nobel that while he gave his

lifelong efforts towards developing and perfecting the most devastating means of warfare, he at the same time was deeply and actively interested in universal peace, and his ideas in that regard bear resemblance to those underlying the foundation of the League of Nations. But his was an altogether unusual personality. In his creative activity he was predominantly an extravert, yet while his superior intellect was in the first place directed towards practical tasks, his personality bore a distinct trait of romantic idealism, and while pursuing his activities with unwonted energy, he was possessed in an uncommon degree of Nordic melancholia, which frequently made him depreciate his work. He was a lonely man—he never married—and shy in the extreme.

In his will, dated November 27, 1895, Nobel left practically his entire fortune, 31,400,000 kronor, the accumulated fruit of his inventions, for a fund, the income from which was to be devoted to giving prizes to those who had "done the greatest service to mankind" in the fields of physics, chemistry, medicine, literature and efforts towards peace. The terms of his will were subsequently translated into the statutes of the Nobel Foundation, which received royal confirmation in 1900.

JOHAN LILJENCRANTS

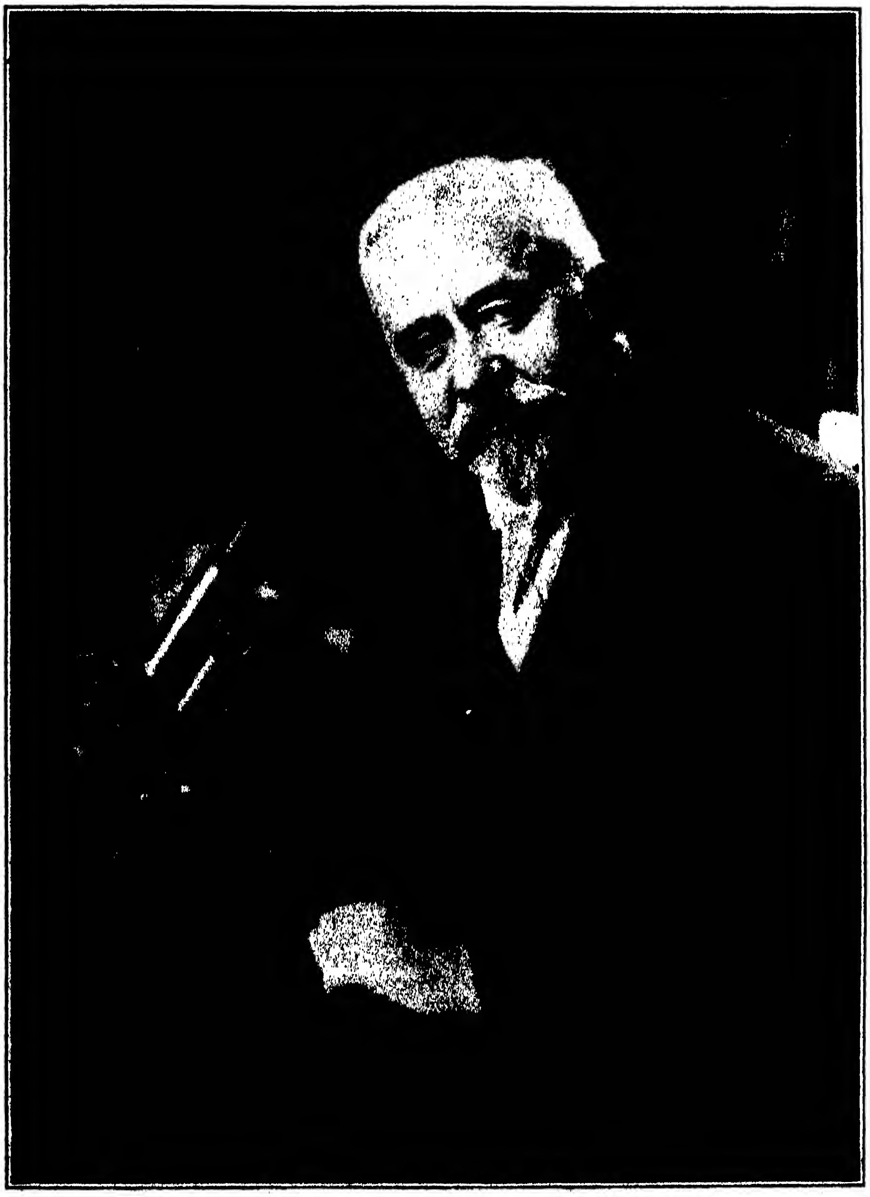
## HALF-MAST ON THE PASTEUR INSTITUTE

THE Pasteur Institute of Paris is draped in double black. On the twenty-ninth of October the famous assistant director, Albert Calmette, died; and five days later, Emile Roux, the director of the institute, passed away.

Dr. Calmette died at the age of seventy years. He was born in Nice in 1863 and inherited the sunshiny character of his birthplace. As a young man he was the disciple of Pasteur, who authorized him to found the Saigon Pasteur Institut in Indo-China and later on the Institut de Pasteur of Lille. He was well adapted for this, because of his wide experience as an investigator and of his first-rate administrative ability. He spent part of his life as naval surgeon and also as professor of bacteriology and hygiene in the University of Paris and the University of Lille.

In spite of the fact that he contributed considerably to the knowledge of anchylostomiasis, purification of sewage, serologic treatment of snake bites and other topics, his main hobby was always tuberculosis. First he became known in this field by his ophthalmic test. He found that if a dilution of tuberculin was instilled in the eye of an infected person or animal a conjunctivitis followed the instillation. This test is still used in veterinary surgery; however, in humans the different skin tuberculin tests were found more simple and not at all dangerous. The greatest contribution of Calmette is the BCG vaccination. He found that a well-planned slight tuberculous infection, achieved by an almost avirulent bovine strain of tubercle bacilli, confers definite immunity against future tubercle bacillus infections. After twenty-three years of animal experimentation, in 1924 he was ready to use his vaccine on human babies. Since this time the BCG vaccination has become more and more popular in many countries, and up to now about two million children have been inoculated.

The French people became quite emotional about this vaccination; Calmette became a national hero. The Lubeck tragedy taught us that in an improperly run laboratory sad errors might happen. The French Government therefore spent 12 million francs to build a special BCG unit to the old Pasteur Institute. A BCG building was erected, which, like a BCG sanctuary, allows in its culture rooms no entry to any other germ but to the BCG, and no other human beings but the



ALBERT CALMETTE

devoted high priests of the BCG culture. In this way the French Government felt assured that the Lubeck catastrophe could not repeat itself on French soil. The new BCG Institute controls the making and distributing of all the BCG vaccine in France.

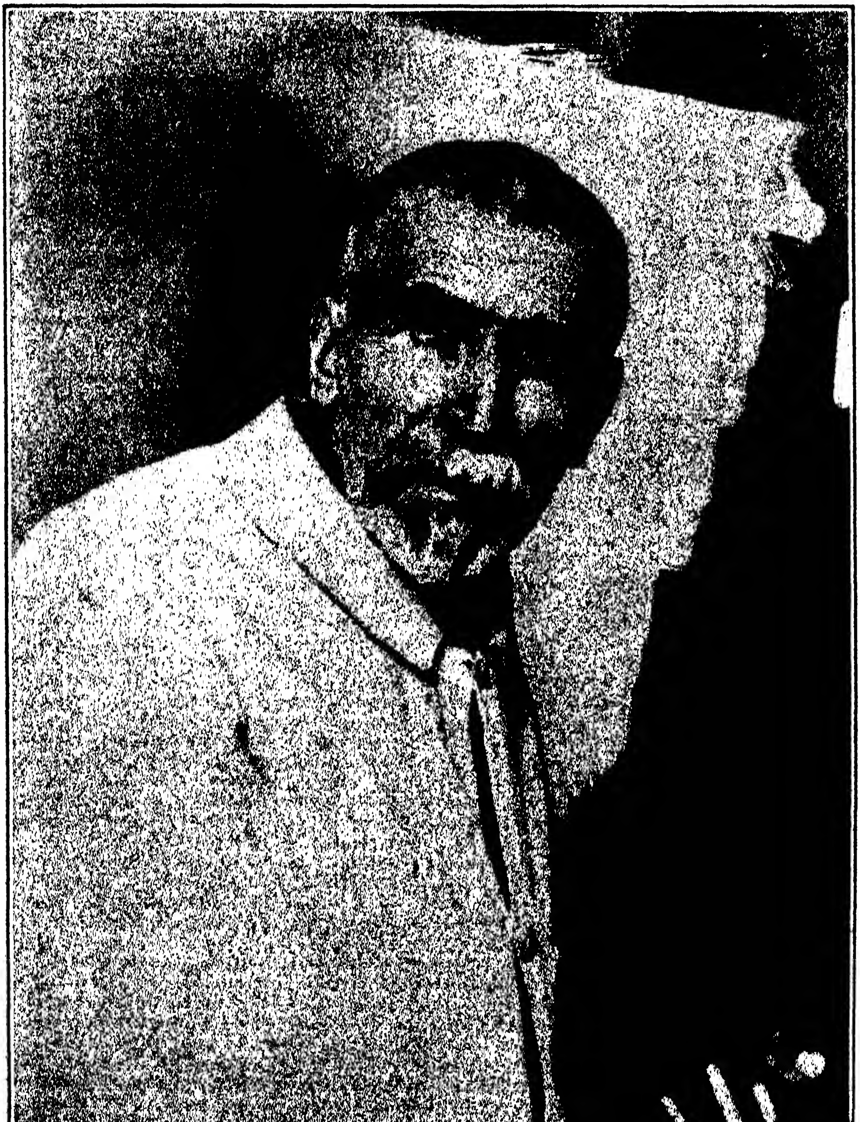
Calmette devoted almost all his time and energy to the BCG problem. He lived in the Pasteur Institute, and every morning at 9 o'clock, sharp, he received his whole staff in his modest working room and listened to a recital about all the happenings of the previous day. He acted toward his staff as a good father acts to his grown-up children, helped them in their scientific and personal problems; made it a point that every one should, so far as lay in his power, be happy and satisfied around him. In the outside world he was just as popular with those who did not oppose his opinions as with those within his laboratory. He was a first-rate orator and could handle any kind and any size audience with theatrical skill. He was honored by being made a member of the French Academy of Science and the Academy of Medicine and was also a visiting member of the Royal Society of Medicine in London. He received just recently the Great Cross of the Legion of Honor from the French Government.

In this country the first BCG vaccine was brought by Nathan Strauss, Jr., and given to Dr. William H. Park to conduct a well-controlled experiment with it. The work has been going on in New York City for the past seven years under the auspices of the health department and with the financial help of the Metropolitan Life Insurance Company. So far the BCG has proved to be not only harmless but also to decrease the tbc mortality to a sixth of the fatality of the controls. Several communities are already giving the vaccine to infants born in tuberculous families.

Calmette's death was most likely caused by coronary thrombosis. He knew for several years that his heart required rest; however, the progress of his BCG vaccination fascinated him so greatly that he kept on working uninterruptedly until death reached him in the midst of his problems in his new BCG laboratory. The mothers of two million BCG vaccinated babies mourn for him in many different countries.

Dr. Emile Roux, director of the Pasteur Institute, died in his eightieth year on November 3, five days after the death of his lifelong friend, Dr. Albert Calmette. Fifty-five years ago, Dr. Roux entered the service of the Pasteur Institute as an assistant of Pasteur. He became a pupil and friend of Pasteur, and was for many years his most talented and valuable assistant and co-worker.

In those early years Pasteur would appear in the laboratory every morning at 9 o'clock and would go over with Roux the next step in the experiments, and Roux and his assistants would then carry them out. His help was invaluable to Pasteur in his researches concerning anthrax, rabies and hydrophobia. As Pasteur grew older, Roux became an independent investigator. Probably the most important work that he carried out as an investigator was upon diphtheria. The discoveries of Klebs and Loeffler, in Germany, had established the fact that the diphtheria bacillus was the causative factor in the development of diphtheria and that it made a specific toxin which did the damage. Pasteur was deeply interested in the nature of this poison, and he detailed Roux, Martin and Chilloux to study its development and whether the toxin was a part of the bacteria or whether it was a separate substance in the culture media. With a Chamberland filter Roux proved that the toxin in the culture fluid was separate from the bacillus, since it passed through the filter. This discovery was of great assistance in the development of antitoxin and the immunization experiments on animals which led quickly to such striking results in Germany and France. In May, 1894, Roux published a paper describing his success in treating success-



ÉMILE ROUX

fully with antitoxin rabbits suffering with the early lesions of diphtheria. He also established its preventive value when it was given before exposure to infection. Control animals, similarly infected but given no antitoxin, regularly died. By February 1, the animal results were so conclusive that Roux presented the Paris hospitals in which diphtheria was treated supplies of diphtheria antitoxin. The first child was inoculated on February 1, 1894, and made a good recovery. The antitoxin treatment was quickly accepted by the Paris physicians. In September he was able to report good results in hundreds of treated children. We can hardly imagine the enthusiasm aroused by this success, as, until the discovery of diphtheria antitoxin, the world possessed no treatment of value. For his work on diphtheria, he shared the Nobel Prize with Behring.

With his collaborators — Calmette, Chamberland, Duclaux, Nocard and Metchnikoff and others—he carried on investigations along various lines, such as on a cholera serum with Guerin and on syphilis with Metchnikoff. He was very jealous of his institute and of the reputation of the workers in it. He did not take kindly to statements contradicting their conclusions, unless he became convinced of their correctness.

Dr. Roux led an ascetic life. He never married and lived in very simple quarters near the Pasteur Institute. His regular diet was bread and soup. He slept on a hard camp bed. For the past forty years he suffered from an arrested tuberculosis. He took a deep personal interest in all those working in the institute, from his collaborators down to the cleaning women. After he became the director of the institute, he was able to do little individual work, as most of his time was taken up with his administrative duties, the reception of visitors, his consultations with his associates, his committee meetings and his visits to those of the institute who were ill.

On his seventieth birthday, at a meeting in his laboratory, Dr. Roux spoke of the joys of scientific labor not dictated by personal advantage and described the untold satisfaction he found in research and discovery.

Dr. Roux died after a prolonged attack of the grip. He was also depressed by the death of his friend, Calmette, in whose work on the prevention of tuberculosis he was deeply interested and which he supported by his influence. Until his last illness he was able to attend to his duties at the Pasteur Institute. His unusual memory and his ability to help the members of his staff by friendly criticism remained almost unimpaired till the end.

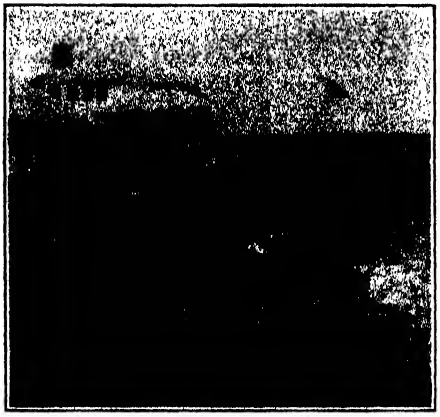
WILLIAM H. PARK

## A NEW SEISMOGRAPH STATION

THE new seismograph station of the Massachusetts Institute of Technology, now in operation in northeastern Maine, is the most easterly on the North American continent. Hitherto, no regular seismic observations had been made in this section of the country, the nearest instruments being located at Harvard University in Cambridge and at the Dominion Observatory at Ottawa, Canada.

The station, which has been in preparation for several years, represents one of the most advanced in the design of instruments for recording earthquakes. The isolation of the station, with freedom from artificial disturbances found in and near cities, is considered of great importance, and it was because of this fact that the summer engineering camp of the institute's department of civil engineering near Machias, Maine, was chosen as the location.

The records of the seismographs are sent directly to the headquarters of the U. S. Coast and Geodetic Survey in Washington, where similar records coming from widely separated stations make it possible to determine accurately the



AT TECHNOLOGY CAMP

origin of seismic disturbances. The new station is in charge of Professor George L. Hosmer, who during the summer makes his headquarters at Camp Technology.

The building in which the instruments are housed is constructed of concrete, with walls nine inches thick. The interior is lined with two layers of insulating material, separated from the wall and from each other by air spaces. The concrete pier on which the instruments are installed has its foundation on an outcrop of volcanic rock which underlies this section of Maine near the shores of the Bay of Fundy.

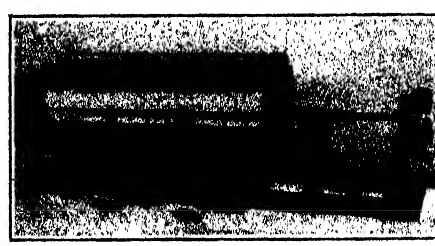
The seismographs, which were designed and built by Dr. Frank Wenner, of the U. S. Bureau of Standards, consist of two separate units, one for recording east and west movements of the earth and the other to detect waves of north and south direction. The slightest earth tremor registered by these delicate instruments sets up an electric current, which is transmitted by a special cable to the recording instruments in a building nine hundred feet from the seismograph house.

THE SEISMOGRAPH HOUSE

The recording room, located in the basement of the home of E. O. Dennison, resident superintendent of Camp Technology, is light-proof and, in addition to the instruments for receiving earthquake data, is equipped for developing the photographic paper on which the records are registered.

THE RECORDING ROOM

SHOWING THE RECORDER, THE GALVANOMETER AND THE CLOCK.



THE THREE-DRUM CLOCK-DRIVEN RECORDER

The electric currents generated when the seismographs register an earthquake operate an extremely sensitive galvanometer, which, by means of a tiny mirror, writes the message of a distant earthquake with a pencil-point of light. The record is registered on a revolving drum, covered with specially prepared photographic paper. The drum is driven by an accurate clock mechanism, and the exact instant of the beginning and ending of any earth disturbance is automatically noted on the record.

## A GROWTH-STIMULATING ACID

PANTOTHENIC acid is the name given by Professor Roger J. Williams, of Oregon State College, to a newly discovered physiologically potent substance, because of its wide-spread occurrence in tissues. In its strictest sense, the Greek word means "from everywhere," and while this acid does not occur either in the stratosphere or beneath the earth's crust, it is so wide-spread that he has found it in all types of living cells—from the tissues of higher animals and plants down to the lowlier forms of life, earthworms, oysters, yeasts, molds, algae and bacteria.

Physiologically active substances, such as hormones and vitamins, are often of limited occurrence and inhere in certain organs and tissues. In no case has it been proved that such a substance is of universal biological occurrence. Pantothenic acid, however, is common to all types of living things. Further research may show that it is one of a group of substances which occurs universally in living matter in very small amounts.

The substance is recognized by its remarkable effect on yeast growth. That its identity has not been established before is due to the fact that it occurs in tissues in very small amounts and also because of its chemical nature—it is an aliphatic hydroxy acid and hence very difficult to crystallize.

By converting the acid into an alkaloidal salt, then after recrystallization into its calcium salt and finally by making use of fractional electrolysis, the acid is obtained in a very highly concentrated form, perhaps approaching purity. The fractional electrolysis in a multiple compartment cell segregates acids and bases of different strengths in the different compartments. The acid, so obtained, can be detected when one millionth of a milligram is present in a cubic centimeter of culture medium.

When this acid is added to a medium containing all the known nutrients for yeast, including inositol and the rarer elements, its effect is striking. Without any of the acid present (except for the small amounts added with the seed yeast or introduced as an impurity with cane sugar) the yeast may multiply tenfold in twenty-four hours. But when pantothenic acid is added, the multiplication may be anywhere up to 100,000-fold or more, depending on the amount added to the medium.

The fact that pantothenic acid has such a striking effect on yeast growth and multiplication, coupled with the observation that it is found in all types of living tissues, suggests the probability that it may have fundamental functions in connection with the general process of growth as known in the animate world.

A further observation which lends interest to this possibility is the fact that organisms which are capable of very rapid growth, such as yeasts, slime molds and mushrooms, are rich sources of the acid. On the other hand, pathologic growths, such as carcinoma, are not associated with large amounts of the acid.

The origin of the acid in nature is as yet obscure. It is not produced by yeast as it grows but is synthesized by *Aspergillus niger*, one of the common molds inhabiting the soil. It is quite possible that the acid, rather than being produced by green plants, is formed in the soil and stored in seeds for the growth stimulation of young seedlings.

Many lines of research are opened by the discovery of this acid. The determination of its exact chemical nature and devising a method for its laboratory synthesis will be important objectives. As to its functions, investigations are under way to determine the rôle which it plays in the growth of other types of yeast, of bacteria and molds and of higher plants and animals.

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